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PRODUCT ENGINEERING

McGRAW-HILL WEEKLY FOR DESIGN ENGINEERS · APRIL 17, 1961

Design of office copier goes full circle
Chief engineer (center) invented system and built first working model. Project engineer (right) built the first product and developed appearance of final product (foreground) to design sketch held by department manager.

...SEE PAGE 3

PICK THE RIGHT MECHANICAL COUNTER ... PAGE 41

SELECTION GUIDE TO HIGH-DAMPING MATERIALS ... PAGE 44

HOW TO ANALYZE DEFLECTION OF SLEEVED SHAFTS ... PAGE 60

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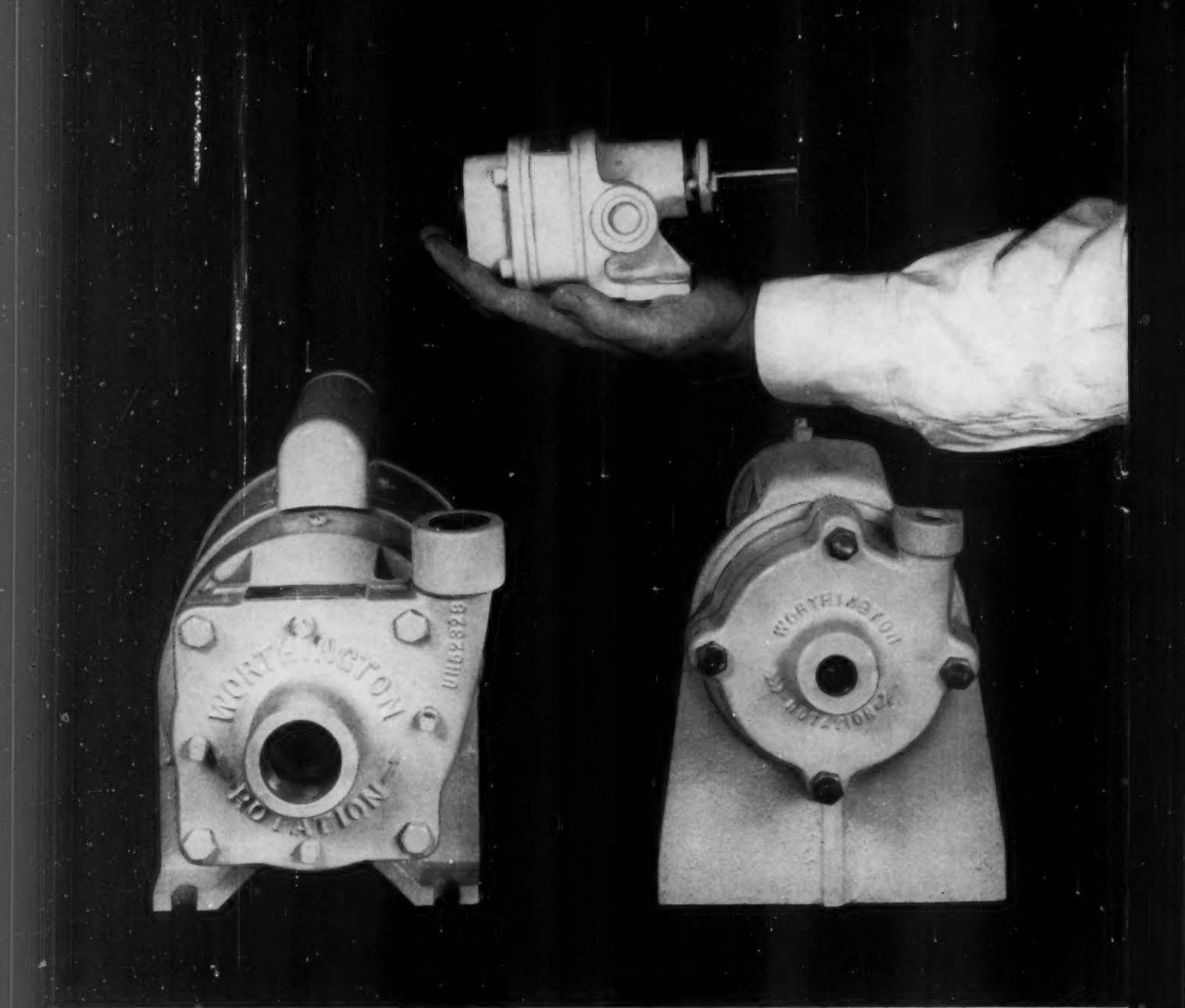

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Yes, we're big in small pumps, too . . . so big that we have a complete, separate plant* for their production. But the real proof of how we can meet your small pump needs lies in the extent of our small pump lines. Look how these three new models stretch down to cover many more "small pump" applications.

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*Located in East Orange, N. J. Our main large-pump plant is in Harrison, N. J.

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PRODUCT ENGINEERING

McGRAW-HILL WEEKLY FOR DESIGN ENGINEERS

April 17, 1961 Vol. 32, No. 16

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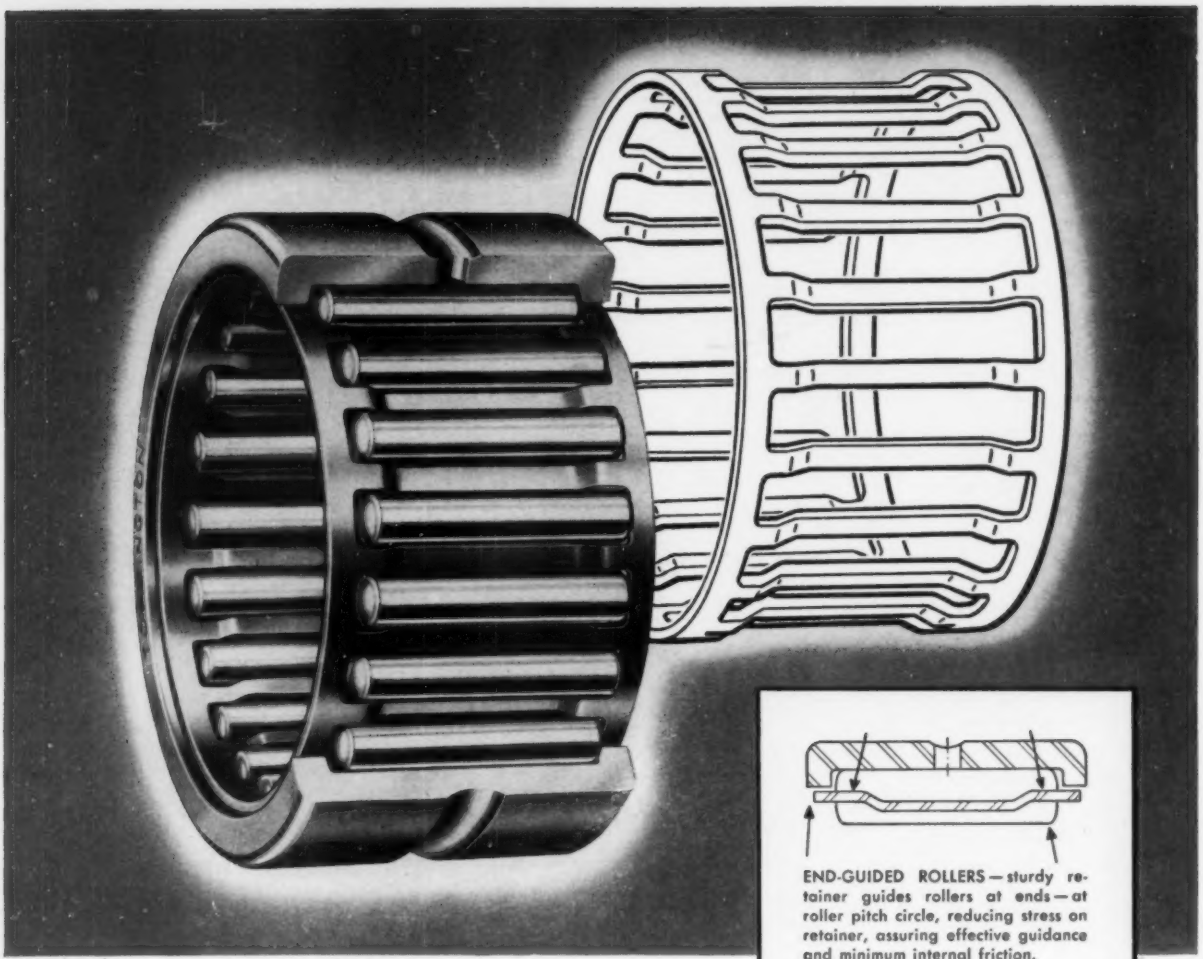


The New *Torrington Heavy Duty Roller Bearing*

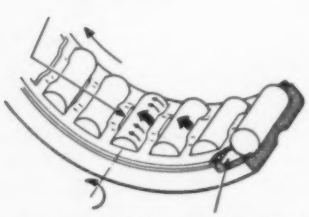
Key to Long Life... Roller Guidance Where It Counts!

This sturdy flange-riding retainer in Torrington Heavy Duty Roller Bearings insures the highest degree of roller guidance where it's most effective... at the roller ends along the pitch circle. You get outstanding service life through minimum internal friction, high roller stability and efficient lubrication.

Controlled contour rollers prevent high end-stress concentrations. Careful heat treatment of the channel-shaped outer race insures high shock resistance. The Heavy Duty Roller Bearing has proved successful under unusual conditions of deflection or misalignment. Torrington Heavy Duty Roller Bearings are giving longer life in such difficult applications as two-cycle engines, hydraulic pumps, oil-field equipment, sheaves and transmissions. For design and application assistance on the Heavy Duty Roller Bearing—and every basic type of anti-friction bearing—call your Torrington District Engineer.

END-GUIDED ROLLERS—sturdy retainer guides rollers at ends—at roller pitch circle, reducing stress on retainer, assuring effective guidance and minimum internal friction.

UNIFORM LOADING—Torrington controlled contour rollers eliminate stress concentration at roller ends. End-stress pattern of unrelieved cylindrical rollers is shown in black outline. Area in gray shows uniform loading over entire contact length of Torrington rollers.



AMPLE LUBRICANT STORAGE AREA is provided by the retainer design, which also allows unrestricted flow of lubricant within the bearing.

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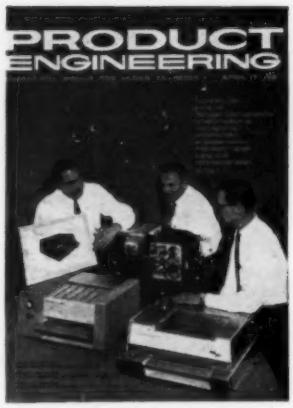
INTERESTING TO NOTE



On our cover—three men in Ozalid's Equipment Operations department are responsible for the new Transfer-A-Matic office copying-machine; it uses continuous-roll feed with development and paper cutoff. The men are (left to right): John Roberts, manager of the department; Fred Franz, chief engineer who conceived the system and put together the first working model, shown in the background; and Carl Ackerman, project engineer who built the first product and is responsible for the machine's appearance. Design story on page 57.

One of the earlier methods of copying or art reproduction was lithography—invented by Alois Senefelder in 1798. America's most famous lithographers, Currier & Ives, imported special flat porous stones from Bavaria. The stones were then prepared by rubbing two of them together with a fine layer of flint dust sandwiched in between. A drawing, made by grease pencil or crayon on paper, was then transferred to the stone. Next, the surface of the stone was sponged with a solution of gum arabic in water to render the nonprinting portions receptive to ink but repellent to water. The surface was moistened, then rolled with ink, which adhered only to the printing image.

During the mid-1800s, Nathaniel Currier and James Ives produced lithographs of important news and historical events. On Jan 13, 1840, the steamboat Lexington caught fire in Long Island Sound, killing 100 people. Currier and an artist friend, Napoleon Sarony (later to become one of America's great early photographers) rushed home and lithographed several thousand prints of the Lexington's demise. Never before had news pictures been produced so rapidly. The prints sold for months.

Later, when Currier merged with Ives, German immigrant girls were hired to hand-color the prints as they were peeled off the stones. Although prints depicting

A Currier & Ives lithograph

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current events had high sales appeal for several weeks and even months, familiar American scenes of skating, farming, hunting, railroads and landscapes sold more steadily.

When Currier retired in 1880, new printing processes were already coming into being. One was invented by Currier's best lithographer, Ben Day. Day realized that the grain of the lithographic stone could be duplicated by raised dots on an engraver's plate. By placing the dots together Day created tones and shades. He went on to invent a system of screens which made it possible for newspapers to quickly engrave and print any kind of photograph or drawing. Currier and Ives graphically illustrated the events of this colorful era, but it was Ben Day's son who captured its spirit in writing. Clarence Day broke all Broadway records with his hit play, *Life With Father*.

Plastics for Surgeons

When an ivory shortage in 1868 prompted a billiard ball manufacturer to offer a $10,000 prize to anyone who could furnish a substitute material, the plastics industry was conceived. John W. Hyatt (a founder of General Motors Corp, Hyatt Bearing Div) won the award with the development of "celluloid." Then, 40 years later, a Belgian chemist, Dr. Leo H. Baekeland, developed "phenolics." The plastics industry grew slowly at first, then, as more and more applications became known, the industry skyrocketed. One of the more recent applications, controlling vibration in structures by applying viscoelastic materials, is the subject of our Special Report, p. 44.

According to a report by Arthur D Little Inc, plastics are being found increasingly useful in surgery and other medical applications. For example, there has been moderate progress in adapting plastic glues for medical purposes. Polyurethane foams have been used as adhesives, and applied directly to fractures and broken bones, but there are complications—foams in general do not provide the necessary strength and if not treated with care, may fracture. An ideal material would permit the patient to move his glued limb within hours and use it two to seven days after setting. Then, eventually, new bone material would grow through and around the plastic film and finally replace it.

Plastics are sometimes used for equipment which takes over the actual life-sustaining processes of the body. Plastic heart valves have been implanted in over 4000 people, and plastic arteries have become well-established surgical aids. A surgical mesh of woven plastic filaments can be used to mend or reinforce areas that will not mend naturally. In the operating room itself, clean vinyl film can be substituted for surgical towels. The skin in the area to be operated on is sprayed with an adhesive and then the sterilized film is fitted on. The surgeon makes the incision directly through the film, and after the operation is over, he either peels off the film and glues or sutures the wound, or he can sew up the incision right through the film.

—Benedict A Leerburger Jr

SIDELIGHT

Talk about advance planning. . . A Joint International Conference on Creep and Fracture has been announced for August 1963. The call for papers says, "Abstracts of not more than 250 words must be received before June 1962." We calculate this allows roughly 14 months from plan to print. Well, isn't it the early bird . . .

NEXT WEEK IN PRODUCT ENGINEERING

. . . Design for Faster Spotwelding

To cut production costs you must reduce production time. This means keeping your eye on several key factors while designing the assembly.

. . . Predict Product Performance

Where does each component fit in eight handy categories? The answer is a strong indicator of the part's ease of assembly and later performance.

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Flexural strength, psi, lw	75,000

(Copper-clad 614 meets MIL-P-13949B, Type GF Plain meets NEMA G-10; approval pending for MIL-P-18177B, Type GEE. Also pending under NEMA proposed FR-4)

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WHAT'S HAPPENING IN RESEARCH . . .

How temperature changes nylon's dielectric properties

Dielectric "relaxation" in nylon may occur even at room temperature, and becomes pronounced at temperatures above 170 F and frequencies above 1 kc, reports Dr A. J. Curtis of National Bureau of Standards; and the relaxation process is frequency-dependent.

At 120 F. the polymer shows a low-frequency polarization, manifested by high dielectric constant and a high loss. Above 170 F, there is a loss maximum; and, even at room temperature, at frequencies above 10 kc, a relaxation process is observable. In this case, at least, it is traceable to water content. Prolonged drying of the polymer can eliminate it.

A low-temperature effect was also observed—a dipole relaxation process which occurs in the temperature range from 0 to −150 F. This, it is believed, is related to mechanical relaxation processes. But, says Curtis, "further data will be necessary before an unambiguous explanation in terms of molecular structure is possible for all of these phenomena."

Magnetic materials tell a new story

New "probes" to explore the properties of magnetic materials, and new types of detectors for high-energy particles may be possible by taking advantage of the effects of fast-particle radiation on solid materials, says T. B. Day of U of Maryland.

When such particles move through magnetic materials, a changing magnetic field is generated which is a clue to the character of both the particle and the field. Day describes it as a combined Cerenkov-spin wave effect that gives rise to a "ringing" of the spin system under certain conditions of frequency and angle of observation.

If suitable insulating magnetic materials can be found and the charged-particle background can be eliminated, the effect might be used to design new types of detectors for high-energy particles and new "probes" for exploring the properties of magnetic materials. A technical report has been scheduled for publication in *Physical Review*.

Note: For information on the Cerenkov effect itself—the luminescence produced by particles when they outspeed light—see *PE*—Nov 2 '58, *p* 10 .

Coatings protect graphite at ultrahigh temperature

Titanium nitride coatings will prolong the life of graphite parts at 4000 F, Langeley Field researchers report. Thin, vapor-deposited coatings made it possible for graphite to retain its strength under high-oxidation conditions for 60 sec or more, while uncoated parts failed after 20 sec.

The mechanism of protection, N. T. Wakelyn of Langley says, is similar to that of oxide protection of aluminum at room temperature: The surface of the nitride reacts with the atmosphere to form a thin oxide coating that protects the nitride itself, and therefore the graphite, from further attack.

Wakelyn believes it should be possible to develop similar zirconium nitride-zirconia coatings for still higher temperatures, and that both types of coatings should be applicable to a wide range of substrates. Furthermore, he notes, because the coatings can be very thin (20 mg/cm^2), danger of failure by thermal stress cracking is slight.

Organic semiconductors: more data coming

There's been no breakthrough, but the possibility of producing semiconducting materials of noncritical composition and in quantity is now attracting world-wide attention, and much new information is beginning to appear. A good deal of Soviet research has already been reported (*PE*—Mar 7 '60 *p* 9 and *July* 4 '60, *p* 9). Now, US researchers, too, are unveiling their work.

American Chemical Society members last month devoted a good deal of attention to the problem. A full-scale conference, sponsored by McGraw-Hill's *Electronics* and Armour Research Foundation, will be held later this month.

Developing organic semiconductors is no easy job. As Jan Kommandeur of Union Carbide points out, many organic substances can be made electronically conductive (Princeton's Plastics Lab, for instance, has prepared nearly half a hundred semiconduting polymers). But this conductivity is different from that in inorganic materials. The charges are "sluggish." They will move only very slowly under the application of a field.

This, Kommandeur believes, precludes certain applications that are well handled by the conventional, inorganic semiconductors. Sluggishness of the organics may make them difficult or impossible for high-speed switching and in some types of diodes and oscillators. On the other hand, the organics may prove valuable for such functions as energy storage where high-speed electrons are not involved.

Work is still in its early stages, but at least a dozen companies are active in the field, and commercialization should not be too far off.

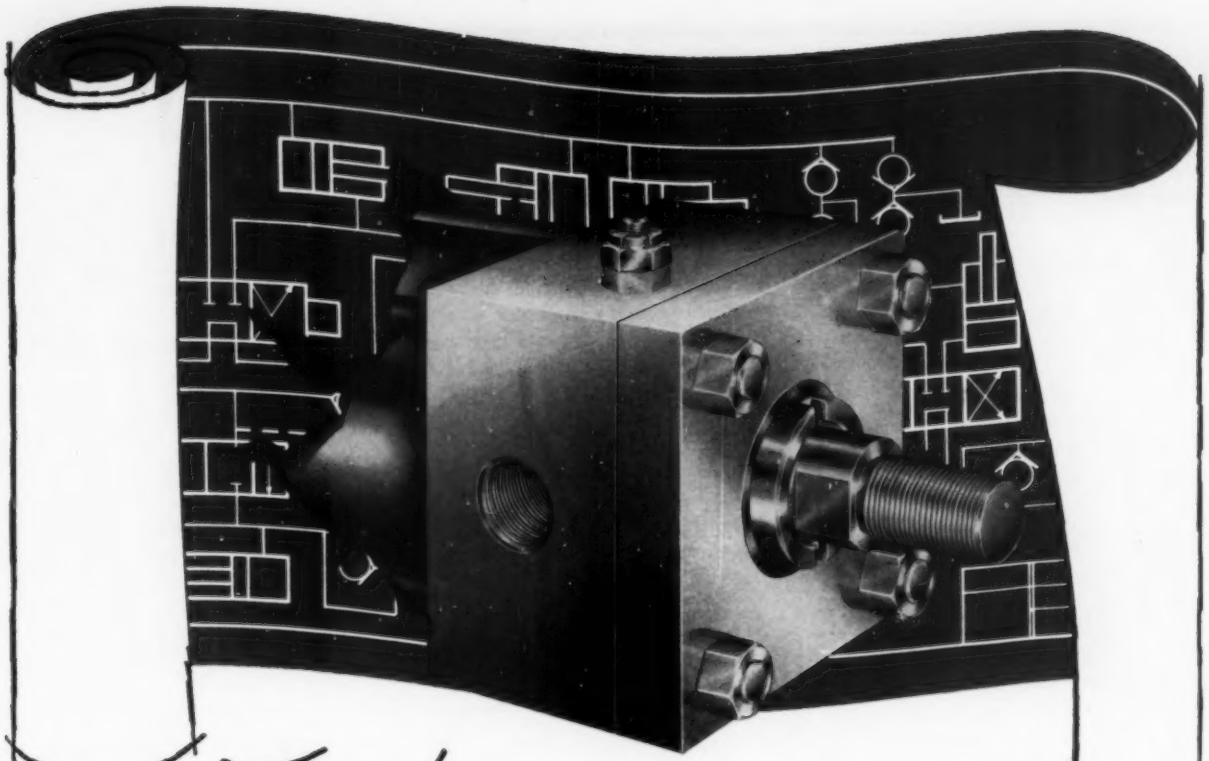
New system measures relative humidity

An instrument that can detect differences of as little as 0.002% in relative humidity has been developed by Agricultural Research Service to study relationships between soil moisture and plant growth.

As described by USDA, the instrument consists of a set of brass tubes, each containing a sample of soil. The tubes are suspended in a water bath held at a constant temperature of 77 F and a thermocouple, with wires attached, inserted in each.

A drop of water is placed on the thermocouple wire, and the unit is sealed. As the water evaporates, it brings the air inside the tube to 100% relative humidity. At the same time, the temperature of the remaining water drops, cooling the thermocouple and changing its electrical output.

In the test setup, 20 tubes are used, and a switching circuit makes it possible to take readings on any one of them. —ARG



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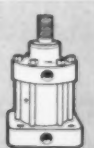
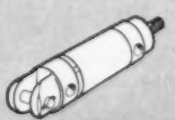


STANDARD HYDRAULIC

STANDARD PNEUMATIC



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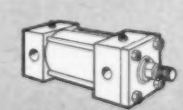

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DEVELOPMENTS TO WATCH...

New compound under test for finishes and lubricants

An old, familiar chemical is coming out soon in a new form that promises a host of new lubricants, adhesives, finishes and coatings. The chemical is colloidal alumina, now being produced by DuPont in a fine-particle, fibrous form. This, the company says, makes it especially suitable for use as a thickener, leveling agent, and filler.

Films and adhesives formed with the new material bond readily with aluminum; and coatings only 1 mil thick are said to provide dyeable coatings even on alloys that normally are hard to dye. Such coatings may also serve as high-temperature (1000 F) lubricants; and, in combination with graphite layers, could be used to provide lubricated surfaces of controlled electrical conductivity.

One property of the "Baymal" alumina fibrils that is expected to be especially useful is their being positively rather than negatively charged. This means an adhesive layer between two negative materials can help hold them together electrically as well as mechanically. Other applications: in ceramics (as a foam stabilizer), glass fiber laminates (as a bonding agent); textiles and plastics (as a bonding agent, antistatic agent, and filler).

New paint dissipates the rust

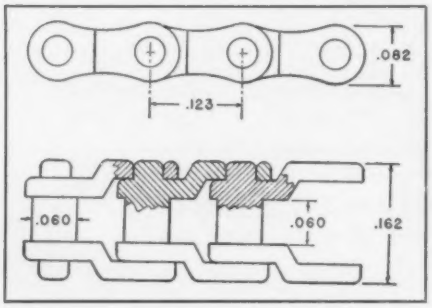
Paints that can be applied as base coats, directly on steel, even if the metal is dirty and rusty, are claimed by National Research Development Corp of England. Key to their success is that they take advantage of the rust itself. They're organic compositions (plasticized polystyrene is recommended) that use iron or steel powders as pigments. When applied to rusty surfaces, a chemical or electrochemical reaction between the rust and the metal powder converts the rust to magnetite; and, in effect, swallows it up. One possible disadvantage: an electrical contact may be established between paint and base metal. But, says NRDC, this can be an advantage, too, in some applications.

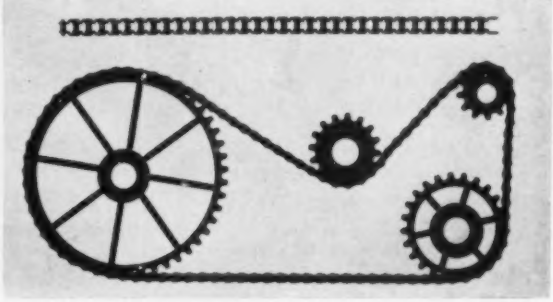
A typical composition will contain about 95% by weight of iron powder and 5% of the plasticized polystyrene, dissolved in xylene. Where a coating of higher hardness is desired, epoxy resins may be added.

Information on the paints, and on formulations suitable for use as undercoats may be obtained from NRDC's US office: Suite 503, Mercury Building, 1925 K St. NW, Washington 6, DC.

Miniature chain for low-cost drives

Tiny chains and sprockets in shaft sizes from $\frac{1}{8}$ in. to $\frac{3}{8}$ in., (see illustration) are being molded of acetal plastic by Bohannon Industries, Colorado Springs. In the chain, "unit-link" design eliminates need for master link and makes length adjustable in $\frac{1}{8}$-in. increments just by snapping links together. The chain runs on either side, weighs about $\frac{1}{7}$ as much as steel, is prelubricated and resistant to chemicals, stands temperatures to 250 F, will operate running loads up to 2-lb tension. Sustained static tension is not recommended, however. Prices, in quantity, will be less than $2 a foot for the chain, about 30¢ for an 8-tooth sprocket; 50¢ for one with 32 teeth.





Flexible sleeving for electrical insulation promises high performance, low cost

Vinyl-coated glass fiber sheathing, claimed able to stand 395 F for periods at least to 20 hr, and to be flexible at −50 F, is being introduced by Borden Chemical (North Andover, Mass, and Compton, Calif). It will be offered in three dielectric grades—2500, 4000 and 8000 volts/mil—and is said to have outstanding flex, abrasion and cut resistance. Prices, says Borden, will be comparable to cotton-base sheathing. Initial production will be in black and yellow, with other colors on special orders; and will be available in Grades BA1, BB1, BC1, and BC2, all to exceed NEMA specifications.

New standards are coming for instrument calibration

Standard glass samples for measuring physical properties will soon be available from National Bureau of Standards. First to be introduced will be soda-lime-silica glass samples for calibrating instruments that measure viscosity, surface tension, and other properties at room and elevated temperature. Next will come a leaded optical glass. A third multicomponent glass (specific type not yet selected) will follow these. Then, NBS plans to start work on high-purity simple glasses.

Also coming up are thermal-conductivity calibration samples for semiconductors, usable in the range 200 to 1800 F. NBS has developed testing equipment and apparatus, is now collecting needed data. It will be at least a year, though, before the samples are ready for distribution.

Plastic elastomer challenges rubber

In wear resistance, cut resistance, rebound, hysteresis characteristics, and resistance to thermal aging, new ethylene-propylene copolymers are showing properties comparable, and in some respects superior, to natural and SBR (GRS) general-purpose synthetic rubber.

First introduced by Montecatini of Italy, the materials are now under investigation by half a dozen US companies and are being eyed as serious competition by natural-rubber producers.

In a report to the Natural Rubber Development Board, Prof G. Gee of England indicated that, of all the synthetic materials, not excluding "synthetic natural" rubber, these copoylymers were likely to give tree rubber its greatest challenge. The reason: the copolymers appear to offer greater cut resistance and reduced heat buildup, without sacrificing other desirable properties, and potentially, they're low in cost. However, he noted vulcanization presents problems, and much still remains to be learned about formulation and fabrication.

Better gas bearings with standard components

Gas bearing performance can be improved, and cost can be reduced, United Kingdom Atomic Energy Authority reports, by reducing the porosity of the bearing sleeve. Any one of several coating systems may be used; among them, shellac and vacuum-deposited metals. With such coatings, says A. G. Montgomery of UKAEA, standard porous sleeves of the type used in oil bearings can be applied to gas systems without causing undue shaft vibration. British Patent 846,742 describes the coating systems. (Note: for more on gas bearings, see last week's PRODUCT ENGINEERING, p 56).

New ceramic for high-temperature uses

Here's a lithium aluminum silicate refractory with excellent resistance to heat shock, low thermal expansion, and good stability at high temperatures—in oxygen and hydrogen atmospheres as well as in air. It's being readied for introduction by Electric Autolite. The company says the material has demonstrated its ability to stand rapid cycling to 1900 F, followed by immersion in cold water, and has been tested in heat-treating and welding fixtures, molding crucibles, and similar applications.

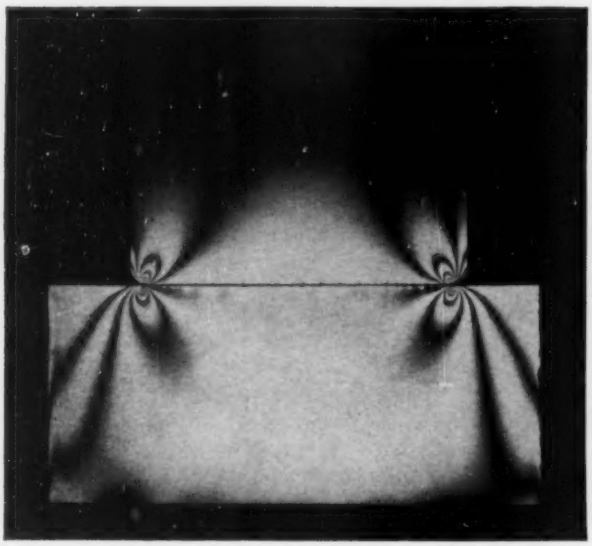
Mechanical strength is labeled "fair."

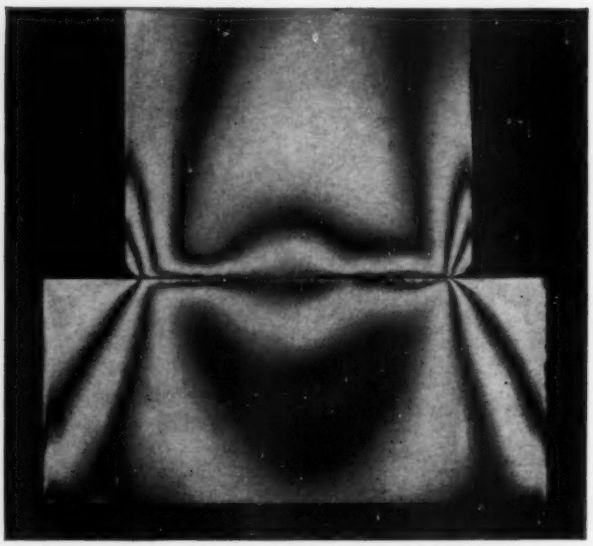
Data on other thermal and mechanical properties is now being assembled, and will shortly be available. —ARG

One in a series of technical reports by Bower

BEARING BRIEFINGS

ROLLER BEARING LIFE AND CAPACITY LINKED TO STRESS DISTRIBUTION





These reproductions of photoelastic studies contain important evidence for every engineer and designer concerned with the performance and selection of roller bearings. In these photographs, the alternate dark and light areas, called fringes, indicate not only the magnitude of stress but also the stress distribution. The photographs were taken by Bower Research Engineers during a study of stress distribution in roller bearings.

The subjects represent rollers and raceways of two roller bearings under identical loads. The illustration at the left shows a roller of conventional design. The illustration at the right shows a Bower "Profiled" roller. That is, the roller is precision ground with a large radius generated along the body of the roller—a predetermined and controlled distance from each end.

The conventional roller photo (left) clearly shows how, under load, stress concentration builds up in and near the roller ends. This is called edge-loading. Such areas of concentrated stress are the breeding grounds for metal fatigue and eventual bearing failure.

In the photo of the "Profiled" roller (right) stress lines can be seen uniformly distributed across the whole length of the roller and raceway. There are no points of excessive stress concentration, consequently no starting points for early fatigue. Such a "Profiled" roller exhibits a great advantage in improved load carrying capacity, a most important bearing requirement.

Under actual operating conditions, Bower "Profiled" roller bearings show a considerably longer life at higher speeds and under greater loads than conventional roller bearings.

Because of this, and of other Bower features to be discussed in later technical reports, we suggest that you consider the advantages of Bower bearings in satisfying your future bearing requirements.

★ ★ ★ ★

Bower engineers are always available, should you desire assistance or advice on bearing problems. Where product design calls for tapered roller bearings or journal roller assemblies, Bower makes these also in a full range of types and sizes.

BOWER ROLLER BEARINGS

BOWER ROLLER BEARING DIVISION — FEDERAL-MOGUL-BOWER BEARINGS, INC., DETROIT 14, MICHIGAN

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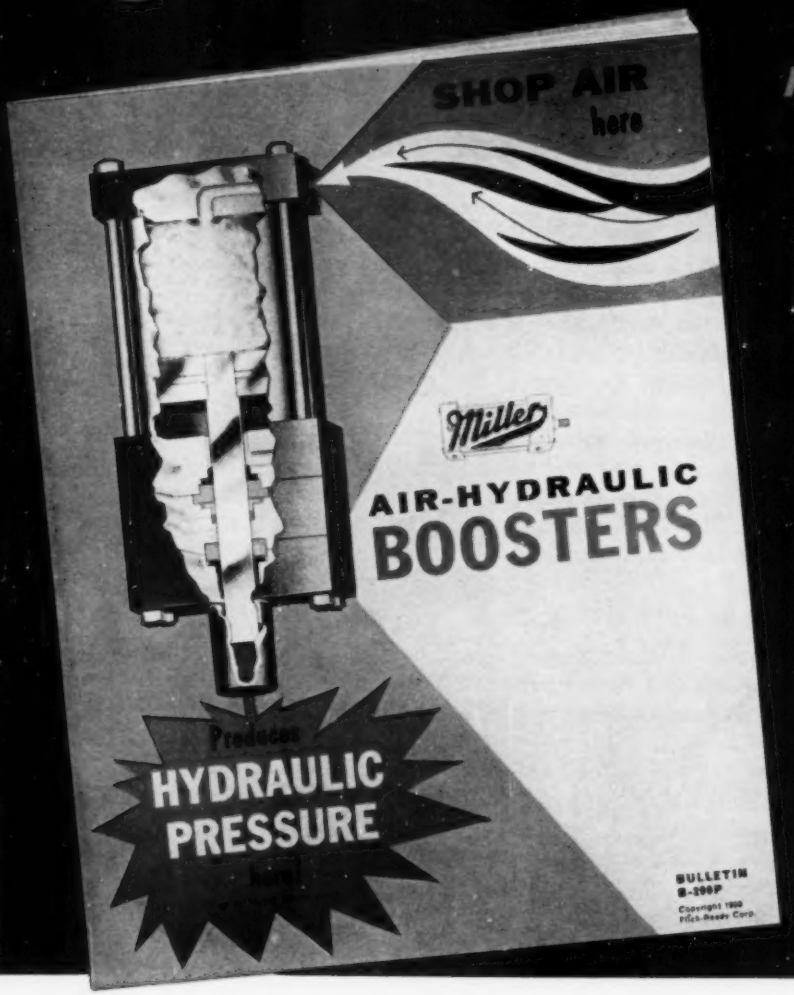

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FROM WASHINGTON . . .

Navy's antisub research reported lagging

A highly classified research ship will start operations soon for the Navy. The Mission Capistrano, a T-2 tanker from World War II, has been altered to conduct underwater sound research.

Right now, the vessel is undergoing tests of its equipment in the Gulf of Mexico. Eventually, it will operate in the Atlantic Ocean.

Navy won't discuss the ship, but unconfirmed reports are that the vessel will instal fixed structures to the ocean floor for sonic experiments. Presumably, the ship is a part of Navy's antisub-warfare program to find better ways of detecting enemy submarines.

Navy may create a "czar" to handle all antisub-warfare research and development. The final decision has not yet been made, but there is a strong push for the measure. Backers of the plan claim that Navy's program has not produced effective means of detecting and destroying enemy submarines.

A splintering of effort in this field is cited as a prime reason for the failure to develop better antisub capabilities. Navy now spends a total of from $80 to $100 million annually on research and development for antisub warfare. But even this money is spread among several Navy offices.

The new plan is to put all antisub research under one office. Some Navy brass, too, want spending increased three to four times the current level.

Present thinking is that the new office would act in a top-level advisory capacity. Actual conduct and administration of the research programs would be left to such Navy offices as the Office of Naval Research.

Research finds surprising ductility in beryllium

A major advance in the production of high-purity beryllium has been made. Under contract for the Navy, Franklin Institute Laboratories of Philadelphia has found that beryllium is not inherently brittle, but impurities remaining in the metal after processing make it so.

The Institute is now working to find and remove the embrittling elements. Single crystals of beryllium already have been produced that are 50 times more ductile than any produced before.

Research on the metal is still in the early laboratory stage, Navy emphasizes. But it promises to be a major advance in metallurgy. For example, beryllium is some 34% lighter than aluminum and 77% lighter than stainless steel; its elasticity is eight times that of magnesium, four times aluminum, three times titanium, and about two times that of steel.

The high melting point of beryllium—2340 F—should permit designs to service temperatures to 1100 F, the Navy says.

Parallel glass fibers increase strength of rocket chambers

Fiberglass rocket-motor chambers reinforced with nonwoven glass fibers may soon become standard equipment for space vehicles. That is what engineers at the Naval Ordnance Laboratory are predicting. Reason is, this type of construction is estimated to be 75% cheaper and three times lighter than metal chambers now in use.

A new test device known as the "NOL Hydraulic Ring Tensile Tester" has been developed to provide quality-control data needed to prepare specifications for making the reinforced plastic material.

Plastics reinforced with parallel glass fibers allow engineers to control the directional strength of a structural item to a degree not possible with woven fabric or random-mat fiberglass. Also, the parallel glass fibers can be packed to occupy over 90% of the volume in a reinforced plastic, which accounts for its high strength.

LOOKING FOR HIGHER EFFICIENCY AND LONGER LIFE IN RIGHT ANGLE DRIVES?

Then take a closer look at Philadelphia Spiral Bevel Reducers. They'll give you an efficiency advantage of 5 to 50% over other types of right angle drives . . . depending upon ratios.

HIGH EFFICIENCY. With efficiencies of 95 to 98%, spiral bevel reducers will lower your power costs . . . reduce the cost of prime movers.

HEAVY DUTY. The bearings and shafting in Philadelphia Spiral Bevel Reducers are designed for 185% overload. Spiral Bevel Gears and Pinions are hardened after they are cut, then lapped to a mirror finish. Helical gearing in multiple reduction units is precision hobbed and shaved from through-hardened alloy steel. Result: greater load carrying capacity, longer life.

COOLER RUNNING. Compared to other types of right angle drives, Philadelphia Spiral Bevel Reducers run cooler. Separate cooling systems are not needed for most applications.

COMPLETE LINE. Philadelphia Gear offers the most comprehensive line of Spiral Bevel Reducers available — or we can build specially engineered units to meet any special requirement. Ratios from 1:1 to 238:1. Single, double or triple reductions in either vertical or horizontal types. Catalog SB-60 gives full selection data. Write on your company letterhead for your copy.

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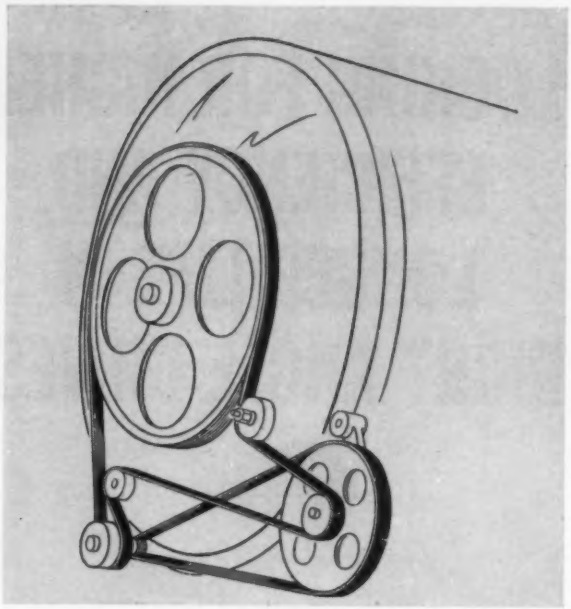
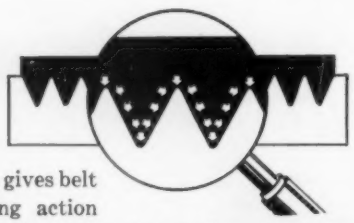
DAYTON POLY-V® Drives pack more power in smaller spaces



Offer engineers greater versatility in drive design

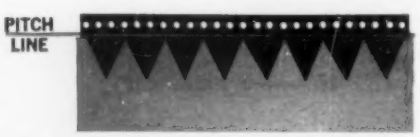
Dayton Poly-V Drives are *single* units. They run in sheaves designed to mate perfectly with belt ribs. This provides twice the tractive surface per inch of sheave width . . . *up to 50% more power in ⅔ the space.* Result —a more compact, lighter drive . . . less shaft overhang.

Greater horsepower capacity



Full contact design gives belt ribs greater gripping action in sheave grooves. Belt tension is transferred equally and in all directions through the belt ribs to the sheave groove walls (hydrostatic principle).

Uniform speed ratios

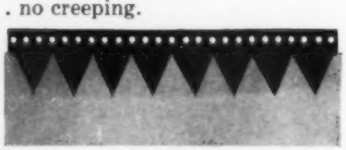


Full contact design distributes the load equally over the entire contour of the V-ribs. Peak loads cannot cause the Poly-V belt to ride lower in the sheave grooves. Pitch diameters and speed ratios remain constant from no load to full load condition.

Vibration free

Full contact design guarantees smooth, vibration-free operation. Full molded surface has complete contact with the sheaves. Poly-V belts have uniform belt thickness—no slipping . . . no creeping.

Greater flexibility



Reduced belt thickness means smaller sheave diameters (as small as ¾" with "J" belts)—less centrifugal force. This permits operations at higher belt speeds (up to 10,000 FPM for Poly-V "J")—ideal for high speed motors.

Simplified drive design

Only 3 Poly-V cross sections are required:

"J"—from fractional to 10 HP
"L"—for intermediate drives (5 to 50 HP)
"M"—for high HP drives (25 HP and up)

See your Dayton engineer

Let Dayton's Engineering Service help you with your drive design. Call or write:

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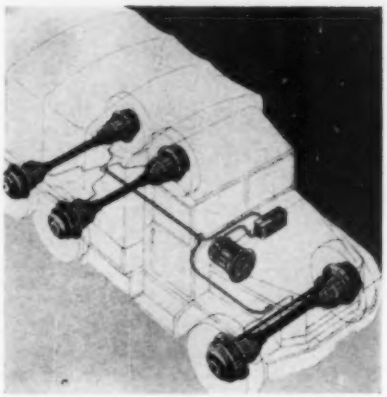
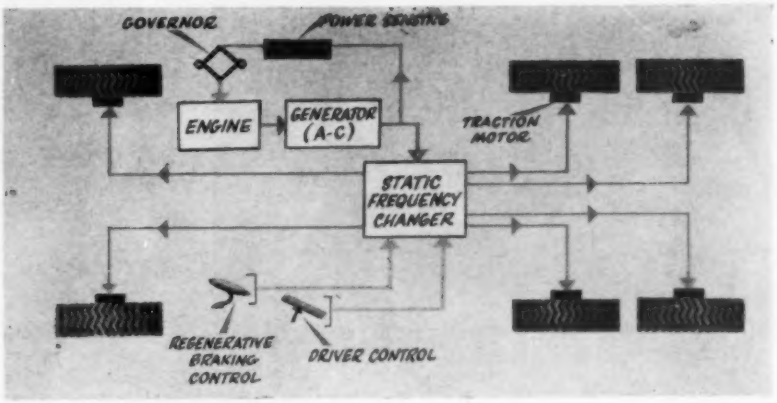
THE ENGINEERING WEEK





LAYOUT AND BLOCK DIAGRAM of proposed ac transmission for US Army M-34 truck.

Static Frequency-changer Key to High-power Wheel Motor

DETROIT—A 3-way collaboration has developed a new US Army truck. It is the result of work done jointly by Jack & Heintz and Reo Div of White Motors Co for the US Army Ordnance Tank-Automotive Command. The truck, result of a $3-million development program, is based on an existing vehicle, the 6 x 6 Model M-34 with its 145-hp, 6-cyl gasoline engine. But in the new vehicle this engine will drive a high-frequency unregulated alternator which, in turn, feeds energy through static frequency-changers to induction-type, squirrelcage traction motors at each of the six driving wheels.

Development work for the new unit was commissioned to eliminate disadvantages found with wheel-mounted motors on present off-the-road vehicles —limited speed range and failure to give total power throughout the speed range. Besides achieving these goals, the developers claim other significant advantages for the system:

• **Weight reduction**—The proposed truck weighs 1800 lb less than a production M-34. This would appear to be true if a smaller engine is used and frame construction changed.

• **Simplified maintenance**—Conventional axles, transmissions, transfer cases, differentials, driveshafts and the necessity for hydraulic power steering are eliminated in the new design. The electrical components replacing these are packaged around OTAC's modular concept which permits component replacement by relatively untrained field personnel. The solid rotor alternator and the squirrelcage induction motors eliminate maintenance of commutators, brushes and slip rings.

• **Operating economy**—Since the engine is not tied directly to the drive train, it can always be operated on a minimum fuel-consumption profile.

• **Design flexibility** – Although a conventional reciprocating engine is the prime energy source now, it could easily be replaced by any new product such as a multifuel engine, a turbine, a fuel cell, or conceivably in the distant future, a compact nuclear power plant. A turbine would eliminate need for the present gear step to the alternator.

• **Ground clearance**—As installed on the otherwise unaltered M-34, ground clearance is improved by 5 in. On an all-new design, over-all height could be reduced accordingly.

• **Power source**—When not performing its function as a vehicle, this unit can be used as a stationary power source. Any ac combination ranging from 110v/60c to 220v/400c is available, plus a simultaneous supply of 28v dc. Military applications and savings in this area are broad.

• **Fail-safe**—Thanks to electrical isolation, damage to the drive at one wheel will not affect power supply to the other wheels. The vehicle can be driven with one to five drive units out of commission, assuming the failure does not cause a wheel to lock.

• **Application**—The fundamentals of this power system can be applied to any wheeled or tracked vehicle.

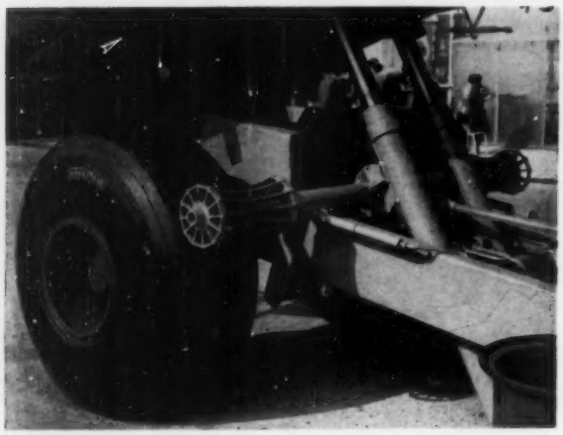
The static frequency-changer contains silicon-controlled rectifiers and changes the 3-phase variable frequency of the alternator to a single-phase constant frequency. Alternator output varies directly with engine speed and may range as high as 10,000 cps. The changer converts this to 6 to 400 cps for the wheel motors. A driver-controlled "accelerator pedal" sets electric motor speed by varying the output frequency of the changer.

Vehicle braking is achieved by lowering the frequency of the motor in relation to its rpm. Under these conditions, the motors act as alternators and cause the main alternator to drive the engine.

The motors at each wheel feed through a 2-speed planetary gearbox equipped with an electromechanical clutch. This, coupled to the necessary wheel drive and the static frequency-changer, weighs less than 60 lb.

A spokesman for Jack & Heintz states that all components of the new truck have been assembled and bench-tested. The company is currently negotiating with OTAC for a contract to construct prototypes, and says it could have one operating within 12 months. It has also aroused "considerable interest" by makers of truck and off-the-road equipment.

—Del Yannatta, Detroit News Bureau



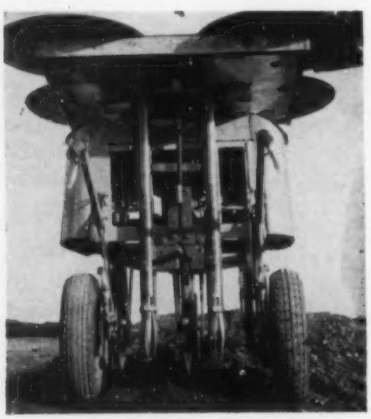
POWER ASSIST—French idea for semitrailer wheels.

POTATO DIGGER by Kuhn Freres is mounted cutter-bar fashion on a tractor. The share, with attached potato-cleaning screen, is oscillated by an eccentric driven by the mower's wheel crank through a belt. Depth is regulated by a caster wheel.

Torque Amplifier and Power Assist Win Agricultural Awards

PARIS—A transistorized electric fence control and an automatic shutoff for milking machine bowls were two items that turned up along with two dozen heavy machines on the list of equipment singled out for technical honors by a committee of experts at this year's International Agricultural Machinery Show. Among the more interesting mechanical items:

• New Holland Machine Co's bale thrower, the only American machine to win a "Machine Selectionnee" award. Wide rubber belts pick up bales as they leave the baling channel, and flip them as high as 13 ft and out as far as 23 ft into a waiting trailer. The trajectory is varied by changing the speed of the small gas engine that drives the belts at up to 33 fps.



CULTIVATOR-TRANSPLANTER will move at speeds to 2½ mph. Disks at top feed plants down through tube to the two-pronged forks which insert plants in the ground.

• French tractor manufacturer Someca (Div of Simca) designed a torque amplifier that steps up torque input to the gearbox from 145 to 217 ft-lb. This gives more power to the traction wheels, is done without stopping forward motion. Originality of design is in having reduction gearing operate through the power takeoff shaft. In normal operation, the 1600-rpm engine output is fed to a double clutch with both disks engaged. Full engine power feeds straight through to the input shaft, with reduction gear freewheeling on the shaft. Disengaging the clutch slows down the straight-through shaft; an overrunning clutch locks the gear connected to the power takeoff gear which now drives the power input shaft at 1050 rpm. Torque amplifier can be cut out by disengaging the pinion on the power takeoff shaft by a dog clutch.

• Another award winner was for a power assist to the wheels of large trailers. The simple, effective system was designed by Ets. Francois Biba. Two friction rollers driven through a gearbox and differential are linked to the power takeoff shaft of the tractor. When the rig bogs down, the friction roller drive is engaged and the rollers forced against the trailer's tires by hydraulic jacks. About 10,000 lb of tractive force can be transmitted to the semitrailer wheels.

• Also honored was a self-propelled cultivator-transplanter by Ets. Russolia of Nice. The unit employs a complex arrangement of connecting rods and ratchets driven off a crankshaft powered by a small gas engine to obtain an automatic planting cycle.

The machine advances in jerks, first spraying a charge of fertilizer and then spading with three blades as it moves along. The wheel-driving ratchets lock to stop the machine for the plant-insertion phase of the cycle, which ends by squirting a half-cup of water on each plant. The machine then moves ahead to start a new cycle as the ratchets release the wheels. Plants are inserted by two special forks fed from the plant-distributing spools on the top of the machine.

—**Arthur Erikson, Regional Editor**

Competitive Markets Are Conference Theme

NEW YORK—"Designing for Today's Competitive Market" is the theme of the Design Engineering Conference and Show, scheduled for Detroit's Cobo Hall, May 22 to 25. There will be 11 conference sessions presenting 22 engineering papers, an opening-day panel, and over 400 exhibitors to keep engineers and executives abreast of the original equipment market.

Some 15,000 components—from microminiature lamps, circuits, and screws to enormous beam sections, internal combustion engines—will be displayed. Many represent the most advanced engineering coming from

the nation's leading research, development and engineering laboratories. More than 100 companies will be showing new types of materials, says a spokesman for Clapp & Poliak, show producers. Also represented will be mechanical components, electrical and electronic parts, fasteners, finishes and various kinds of engineering accessory equipment.

The Machine Design Division of the ASME will conduct a four-day conference, to run concurrently with the show, on a variety of engineering subjects. Plastics, steels, lubricants, material and production control are a few of the papers planned.

An opening-day panel of top-flight automotive executives will discuss their department roles in designing a superior product to meet the continuing competition from home and abroad. They will highlight the interplay among production, purchasing, engineering and sales by prepared discussion and answers to questions from the audience. ■

Segmented Shaft Lines Aid Potash Mining

ESTERHAZY, SASKATCHEWAN—A 350-ft cast-iron shaft liner has overcome one of the main obstacles to opening Canada's vast potash reserves to world markets. The liner, reports the mine-owners, International Minerals and Chemical Corp, seals out unwanted fluids from a troublesome geological fault found between the 1240 and 1439-ft levels of the mine shaft.

The fault, called a "Blairmore stratum," carries oil in some areas, coal in other areas, and may contain water under extremely high pressure. Here, it is composed of water-bearing sand and clay layers.

The 3000-ton liner was positioned in a series of 5-ft-deep rings, each made up of 11 segments. The individual segments measure 5 ft square and weigh 4 tons. A total of 76 were used, extending from the 1130-ft level to 1488 ft.

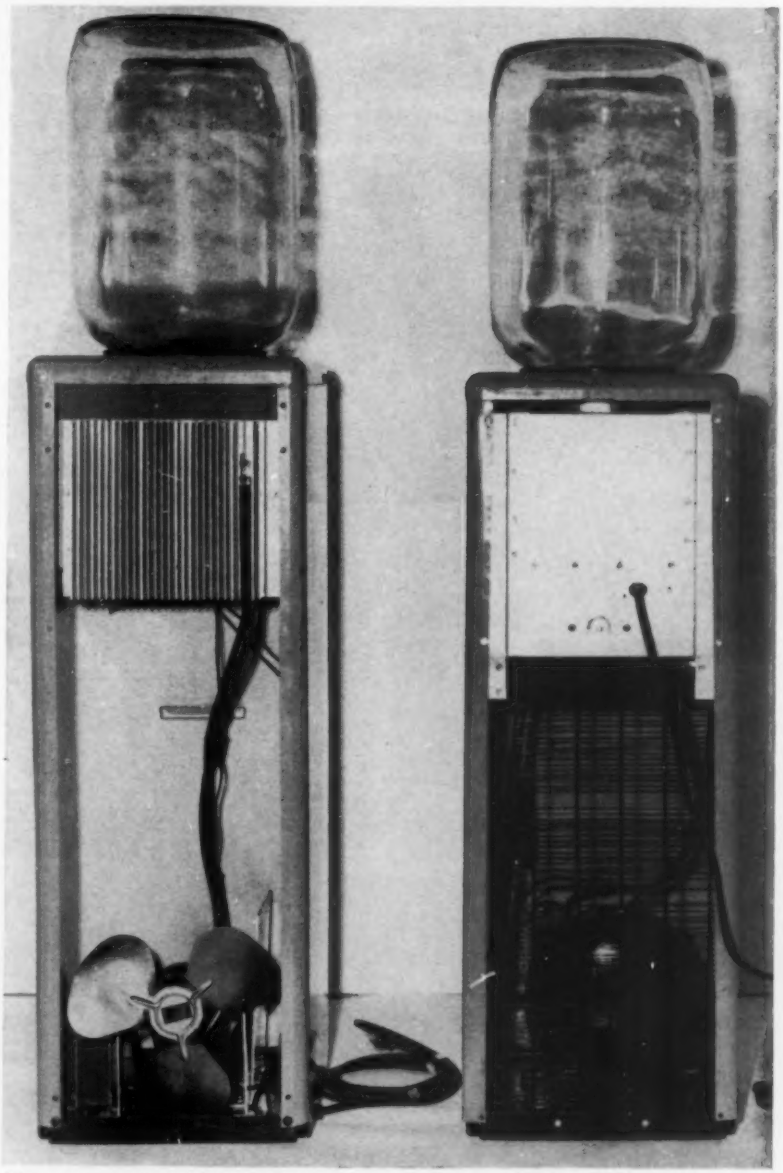
Before excavation could begin, the entire Blairmore stratum had to be congealed over a 50-ft area around the center of the shaft. This was done by sinking 58 freeze pipes, each 250 ft long, into the stratum in a circular pattern and running lithium chloride brine through them. Freezing took almost a year. Penetration of the stratum with pavement-breakers began last fall.

This "freezing and tubbing" technique is new to this continent, but has solved similar problems in Europe.

To avoid possible water seepage at either end of the tubular lining, special sealing rings are used. The final seal between ring and shaft wall is accomplished by wedges of specially imported Nicaraguan pitchpine of various sizes and shapes. These are driven into the void until a sharp steel spike can not be forced into the mass. About 15,000 such wedges are used in each of the three 55-ft sealing circles.

The potash beds are located at 3150 ft and limestone formations in the last 1600 ft are expected to present no unusual problems. ■

Thermoelectricity: Out of the Lab, Onto the Production Line



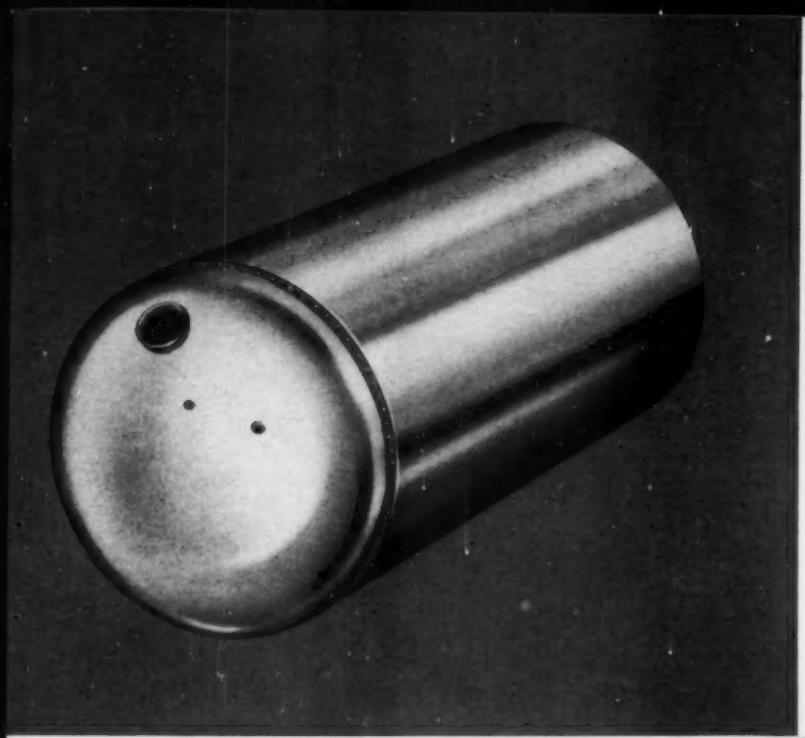
The water cooler at left is the first home appliance by Westinghouse based on the thermoelectric principle. Its cooling components take up about 25% less volume than the conventional unit, at right. In the cooling portions of the thermoelectric version, electricity passes through junctions of dissimilar materials to remove heat. The only moving part is the fan at bottom which is needed to dissipate heat from the cooling elements. The conventional system operates with a "network" heat-exchanger system and motor-driven compressor.

CIRCLE 18 ON READER SERVICE CARD →

REPUBLIC PH STAINLESS STEELS

REPUBLIC A-286

In addition to excellent corrosion resistance, this precipitation hardenable grade is designed to afford elevated temperature creep and stress rupture strength to over 1200°F. Because it is used on critical applications, majority of tonnage produced is processed from ingots that have been vacuum melted by Republic's consumable electrode process. Typical applications: jet engine and gas turbine components such as wheels, blades, frames, housings, afterburners, tail cone parts, and fasteners.



REPUBLIC 17-7 PH* and PH 15-7 Mo*

These steels possess the cold formability of austenitic stainless grades . . . the hardenability of martensitic grades. High strength levels and good creep resistance are maintained at temperatures to over 700°F. and 900°F. respectively. Typical applications: aircraft and advanced missile structural parts, bellows, hose clamps, leaf springs and spring clips, pressure tanks, surgical instruments, antennae.

REPUBLIC 17-4 PH*

Simple heat treatment after fabrication develops high strength levels without excessive distortion or scaling. Unlike most martensitic chromium types, Republic 17-4 PH* is welded without preheating or post annealing, thus resulting in lower fabricating costs. Typical applications: bearings, bolts, shafts, aircraft fittings, gears, splines, mandrels, pins, seats, and valves.

BECAUSE THEY OFFER GREATER VERSATILITY, precipitation hardenable stainless steels broaden the already wide field of stainless steel applicability. Better properties at elevated temperatures are coupled with the formability and corrosion resistance of other stainless grades. Republic PH Stainless Steels are available in the standard mill products. Mail coupon for data.

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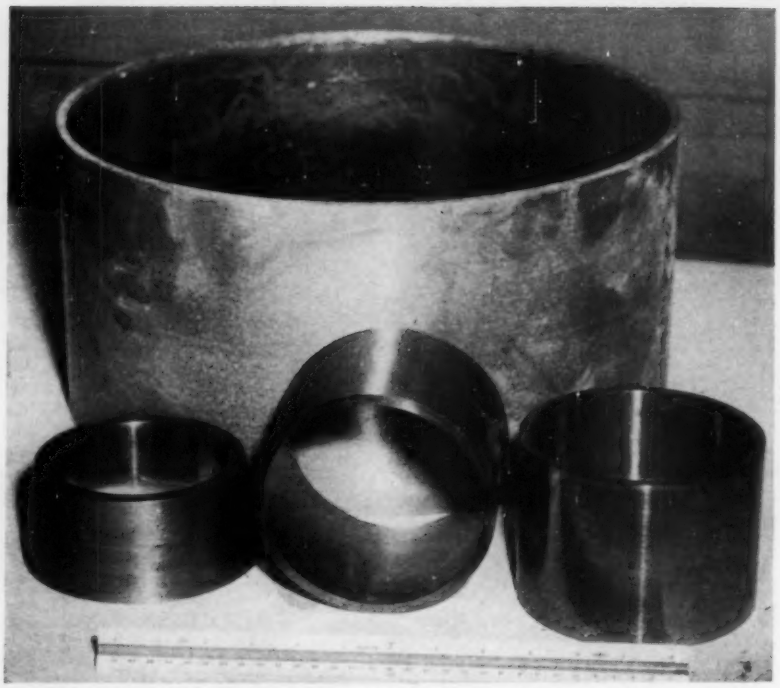
100% Pure Tungsten Is Melted and Cast

ALBANY, ORE—Several years' research on the melting of 50% alloys of tungsten and several months' research on 98% pure tungsten have led to the first successful melting and casting of pure tungsten. Using a centrifugal casting process, Oregon Metallurical Corp is producing hollow rings up to 10 in. OD, and weighing up to 220 lb.

According to Stephen M. Shelton, president of Oremet, a cold copper skull-melting vacuum-arc furnace supplies the heat. The copper crucible is watercooled; the melt is completed in 5 min., after which the pour must be made within 4 sec. One of the largest banks of power rectifiers in the Northwest supplies the necessary 40,000 amps at about 40 v dc.

Besides the substantial economies resulting from casting instead of making shapes by machining forged ingots, Shelton said, the pure-metal centrifugal casting produces a finer grain product than can be obtained with arc-cast ingots. Ordinary sintering does not thoroughly melt the metal, but forms a mass.

—Paul Hansen, Portland News Bureau



THREE MACHINED CASTINGS of 100% tungsten (foreground) are samples of finished products obtained from hollow rings of pure metal cast for first time by Oremet. The larger casting, of molybdenum, was centrifugally cast, but not machined. Oremet is also doing research on tantalum, hafnium, columbium, vanadium.

Alloy Clue Pinpoints Car Trouble 12,000 Mi Away

LONDON—A new method of temperature measurement, which relies on the changes in hardness of certain alloys when heated and cooled, is being used to measure operating temperatures of internal combustion engines. Originated by Shell Research Ltd, at Thornton, Cheshire, the technique is known as the "Hardness Relaxation" method and has solved the problem of measuring temperatures of pistons and valves while the engine is running, enabling hot spots to be pinpointed.

Technique depends on the long-known fact that when some alloys are heated and cooled, their original hardness is changed—the extent of change depending on maximum temperature attained.

Temperature range of the method is about 100 to 1000 C, with an accuracy of plus or minus 3 deg C at optimum conditions—the middle of the useful range of the material.

One application of the technique solved the problem of a car owner in the Australian bush. His car would go for a few miles, then stop. Shell Research, 12,000 miles away, felt that overheating spark plugs were the cause. A set of special plugs with alloy inserts were sent to Australia and were run in the car (on examination at Thornton it was found that temperatures around 1000 C were being reached). Solution: car timing was adjusted to make the engine run cooler, thus curing the trouble.

—Nick Landon, Regional Editor

Another Way to Cut Tire Cost

This three-wheel delivery truck powered by a 2-cyl Kohler K-662 aircooled engine has a top speed of 50 mph. Transmission is provided manually by a Borg-Warner T-96 unit. A right-angle driveline supplies power to the single rear wheel. Front suspension includes Firestone adjustable air springs. The vehicle is 133 in. long, 64 in. wide, weighs 1500 lb. It will be manufactured by the Roustabout Truck Manufacturing Co's plant in Nile, Ohio.

A NEW ENGINEERING MATERIAL

LORD DYNA-DAMP

Dyna-damp panels and structural sections* can be designed in many configurations for addition to existing structures or fabrication as complete damped assemblies.

Lord announces Dyna-damp—a new engineering material that counteracts broad-band "white" noise and vibration. It offers a new, better way to solve acoustic fatigue and structural response problems.

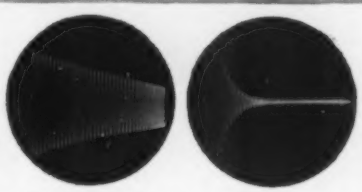
Dyna-damp's laminated design converts vibratory energy into shear strains which are dissipated in a highly damped viscoelastic layer. The damping medium is a special form of BTR® elastomer, bonded between metal elements to give structural integrity and load-carrying strength.

In jets, missiles, ships, vehicles, electronic units—wherever control of resonant response is required—Dyna-damp can introduce dramatically improved performance, higher reliability. It is available to industry in sheet and structural sections or in engineered, finished products for use as primary or secondary structures, electronic chassis, complete mounting systems.

Design engineers can obtain further information and able application assistance on Dyna-damp from the nearest Lord Field Engineering Office or the Home Office, Erie, Pennsylvania.

*patent applied for

Radically improved damping is illustrated by typical decay rate traces.



Undamped: 2024 T-3 aluminum panel

Damped: 3-ply Dyna-damp panel

DYNA-DAMP FEATURES

High strength: bonded construction provides structural integrity across complete part. Ultimate strength: 60% of solid aluminum. Shear strength of BTR layer: over 500 psi. Climbing drum peel strength: over 60 lbs.

Light weight: lighter than aluminum sheet of equal thickness.

Excellent fatigue life: proved greatly superior to aluminum in acoustic tests to 170 db.

Broad temperature operation: −65° to + 250°F.

Ease of fabrication: can be punched, sheared or stretch formed by standard methods . . . fastened by riveting or adhesive bonding . . . sections can also be spot welded.

Environmental resistance: good strength and damping ability maintained after 7-day immersion in aircraft fluids.

LORD®

FIELD ENGINEERING OFFICES

ATLANTA, GEORGIA · CEdar 7-9247
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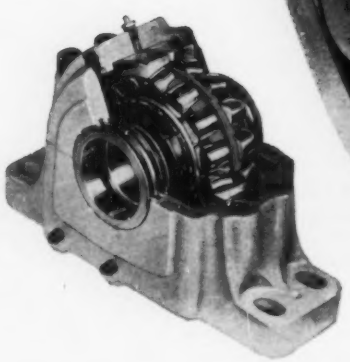
"In Canada—Railway & Power Engineering Corporation Limited"

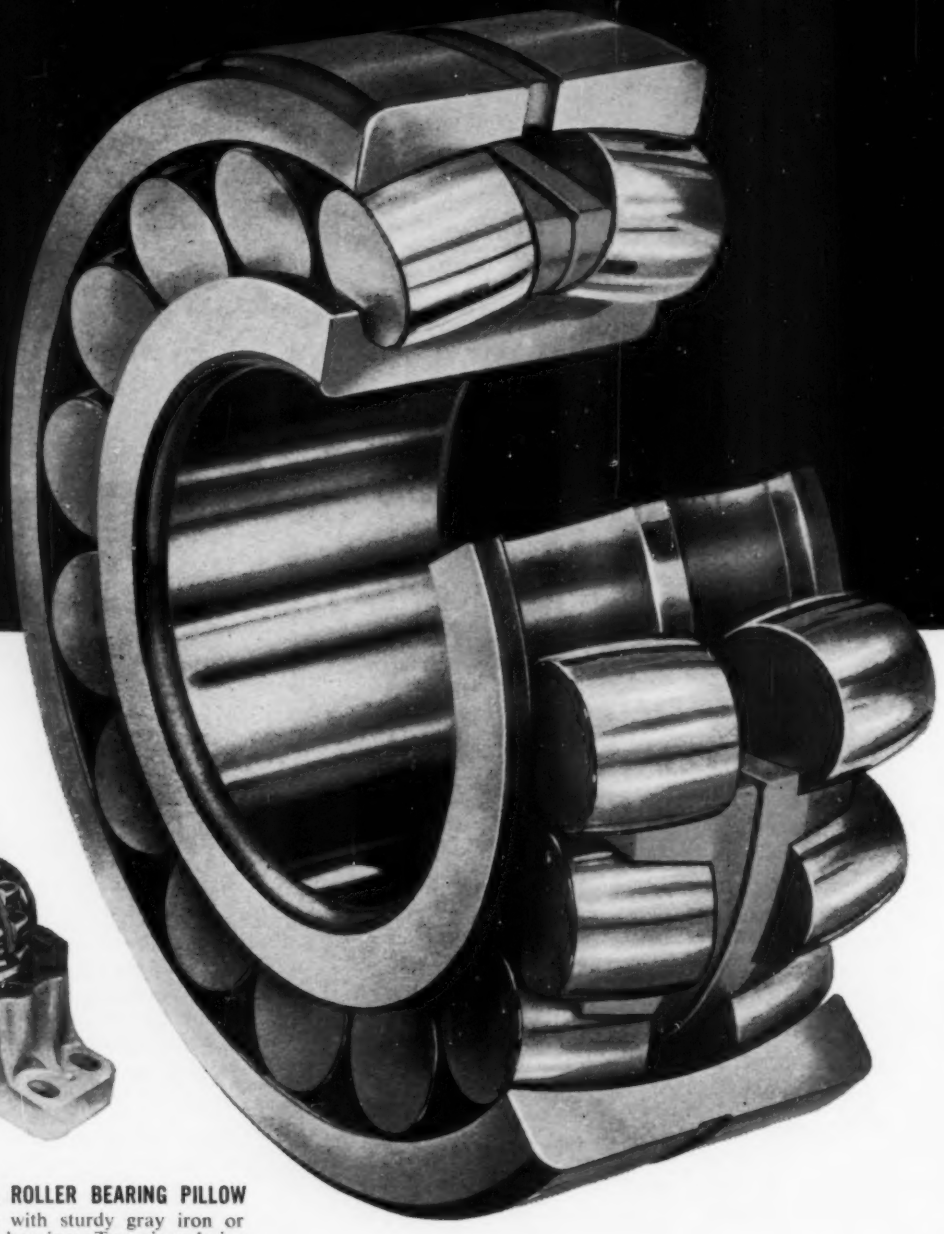
LORD MANUFACTURING COMPANY · ERIE, PA.

CIRCLE 21 ON READER SERVICE CARD

LINK-BELT SPHERICAL ROLLER BEARINGS:

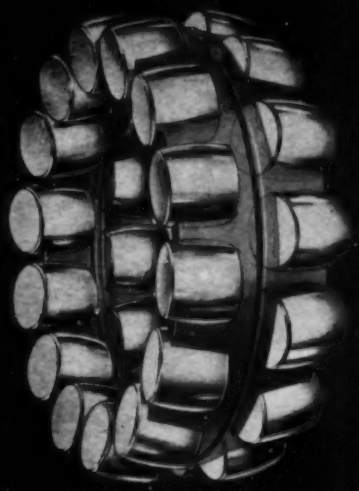
measure these design values

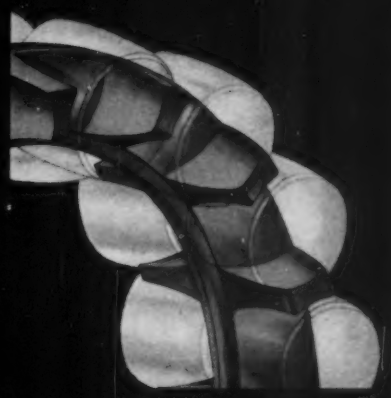




LINK-BELT SPHERICAL ROLLER BEARING PILLOW BLOCKS are available with sturdy gray iron or super-rugged cast steel housings. Two-piece design simplifies mounting . . . permits easy inspection and maintenance without disturbing the shaft position. Link-Belt offers adapter mounting types for shafts from 1 7/16" to 10½" and direct-shaft mounting types for shafts from 1.7717" to 11.0236". Choice of rugged steel, multi-labyrinth seals or Dacron-contact seals.

in terms of your applications





SYMMETRICAL ROLLERS
of maximum size and number

BALANCED PROPORTIONS
of all components

WRAP-AROUND RETAINERS
with double-contoured pockets

Check the ratings—compare any size bearing, any make, with its Link-Belt counterpart. Without exception, you'll find Link-Belt's capacity equal to—and more often, greater than—any other spherical roller bearing design. Reason? MORE ROLLERS, LARGER ROLLERS! Link-Belt offers the *largest effective roller complement* for all sizes of spherical roller bearings . . . rated in accordance with accepted formulas of the Anti-Friction Bearing Manufacturers Association. This increase in effective LDN values (roller length, roller diameter and number of rollers) provides longer bearing life.

Ample thickness above and below rollers to handle loads beyond rated capacity. Largest diameter rollers for maximum capacity.

Boosting bearing capacity involves much more than simply increasing the size and number of rollers. Permissible roller size is limited by the relative dimensions of other parts. Not only must retainers and raceways be able to handle the increased capacity—the overall bearing must conform to international standard boundary dimensions. With *balanced proportions design*, Link-Belt spherical roller bearings meet these requirements!

Retainers of Link-Belt sphericals are precision-machined from centrifugally cast bronze. Far stronger than stampings, these husky retainers consist of independently tracking halves. Wrap-around prongs are double-contoured to the exact shape of the rollers. They extend well below the roller centerline for positive guidance . . . well above for maximum retainment. All sharp corners are removed to eliminate the possibility of wiping action between the retainer edges and the rollers. This feature provides for full roller lubrication even during high-speed operations.

FLANGED BLOCKS

FLANGED CARTRIDGE BLOCKS

CARTRIDGE BLOCKS

TAKEUP BLOCKS

ALSO AVAILABLE FROM LINK-BELT'S SELF-ALIGNING ROLLER BEARING LINE

Link-Belt offers roller bearings with solid housings for shafts from ¾" to 4". They're compact, rugged, easy-to-install . . . employ heavy-duty, double-row self-aligning roller bearings. In addition to pillow blocks, the mountings shown above are also available. Ask for Catalog.

SEE BOOK 2760

for further precision, durability and high-capacity features of Link-Belt spherical roller bearings. Contact your nearest Link-Belt office. Look under BEARINGS in the yellow pages of your phone book.

15,643

LINK-BELT

SELF-ALIGNING BALL AND ROLLER BEARINGS

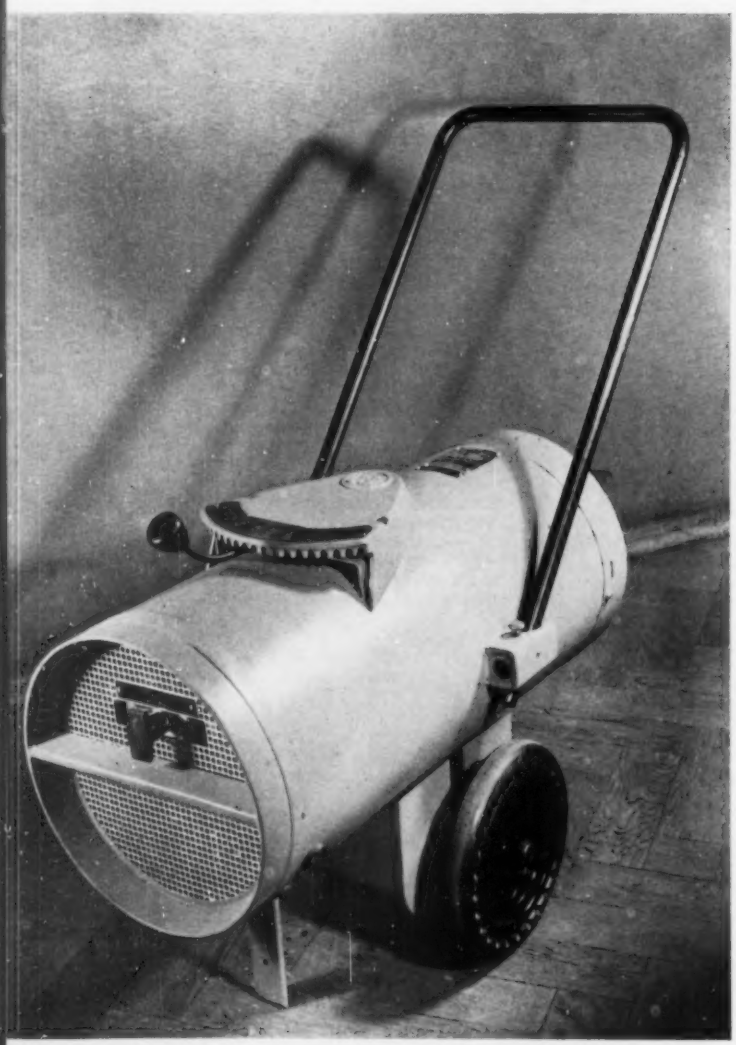
LINK-BELT COMPANY: Executive Offices, Prudential Plaza, Chicago 1. To Serve Industry There Are Link-Belt Plants, Warehouses, District Sales Offices and Stock Carrying Distributors in All Principal Cities. Export Office, New York 7; Australia, Marrickville (Sydney); Brazil, Sao Paulo; Canada, Scarboro (Toronto 13); South Africa, Springs. Switzerland, Geneva. Representatives Throughout the World.

CIRCLE 23 ON READER SERVICE CARD

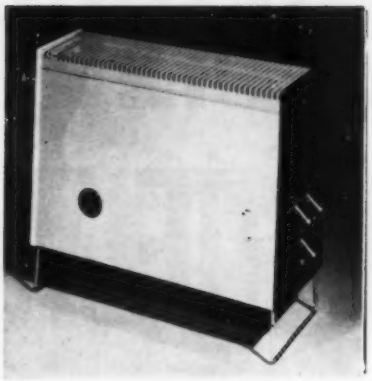
FRENCH DESIGNERS TRYING FOR A "NATIONAL LOOK"

In the midst of one of Europe's most dramatic economic recoveries, French designers are busily feeling their way toward their own accent in product design—as distinctively their own as the design of the Italians or the Scandinavians. But the day when an automobile, washing machine or a lathe can be spotted as "Designed in France" still seems to be a long way off. The leading French designers agree that no national style exists today. A look at their latest efforts substantiates this.

ARTHUR L ERIKSON, *Regional Editor, Paris*



Portable welding machine, made by Normacem (former model above), had its internal elements repositioned by Compagnie de L'Esthetique Industrielle, to provide a more efficient flow of cooling air through the duct-like cylindrical housing. Placing the housing on its "side" made it possible to put the controls on top. Reworked handle permits more normal posture when pushing or pulling and it can be locked in either in-use or at-rest positions. The welding machine's designer, Douglas Kelly, says that at least one reason for the different approaches to product design in France is that industrial design itself is still in an early stage of development—not just because there are few designers and an equally small number of design students—but also because industry is still unaware of the need for product planning and of the more basic approaches to design involved in such marketing concepts.



Space heaters illustrate the divergent approaches of two French designers. The electric heater (above) designed by Bureau d'Etudes Technes for manufacturer Noirot-Kalorik shows the style proposed by Henri Vienot. He feels design should be "free of superfluous decoration and defined by plane surfaces and sharp edges, with the result architectural." Another French design concept is reflected in the gas-fired heater (above, right) by Philippe Charbonneaux. This style aims for "a refined and delicate feeling with warm colors and clean but soft lines. Aggressively sharp angles will be less and less in evidence but forms will nevertheless not give a 'round' impression." The former model (above, far right) of this gas heater, made by Auer, had its radiator (temperatures, as high as 570 F) fully exposed, a potential scorcher for anyone who accidentally touched it. Igniter and pilot light were also out in the open, an arrangement no longer acceptable under French safety standards. The burner-radiator assembly is now enclosed in an enameled and perforated steel wraparound—which permits heat dissipation—and two end stampings, one of them hinged to give access to the igniter and control valve.

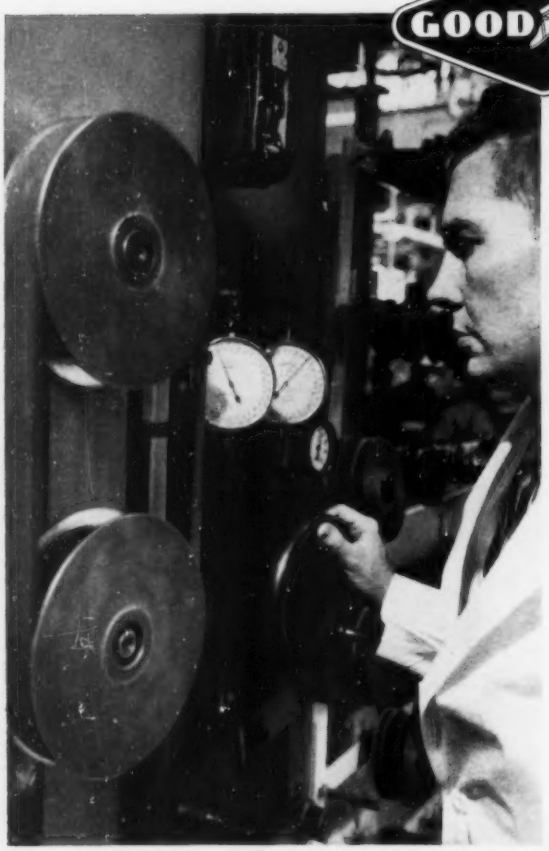
Voltage regulator for TV sets (above) designed by Jean George Viaud for Diapelic gets about as far away as possible from the traditional "black box" look. Housing consists of two plastic shells that are made in the same mold. Reason for the two-step dividing line is "to avoid the consumer's getting the impression that this manufacturer cut corners to hold down cost—a straight dividing line would have made it obvious that top and bottom moldings were identical." This unorthodox approach to electronic equipment typifies Viaud, who is president of the French industrial design organization. He believes that "straight lines and squared-off shapes, cold in feeling sometimes," dominate French product design today. He expects more sculptured forms to develop—with softer lines and an interplay of curved surfaces.

Redesign of kitchen range offers recessed gas burners (above) that provide a continuous ring of flame, without the usual center orifice. This makes it possible to combine the conventional underburner drip pans into a single, sauce-tight tray deep enough to catch and hold an entire pot of accidentally spilled soup. Wire pot supports are stainless steel, which is easier to clean than the usual cast iron. Except for minor changes in the oven-door handle and the knobs, this redesign job made no real change in the range's (right) outward appearance. The reason for this is found in the comment of its designer,

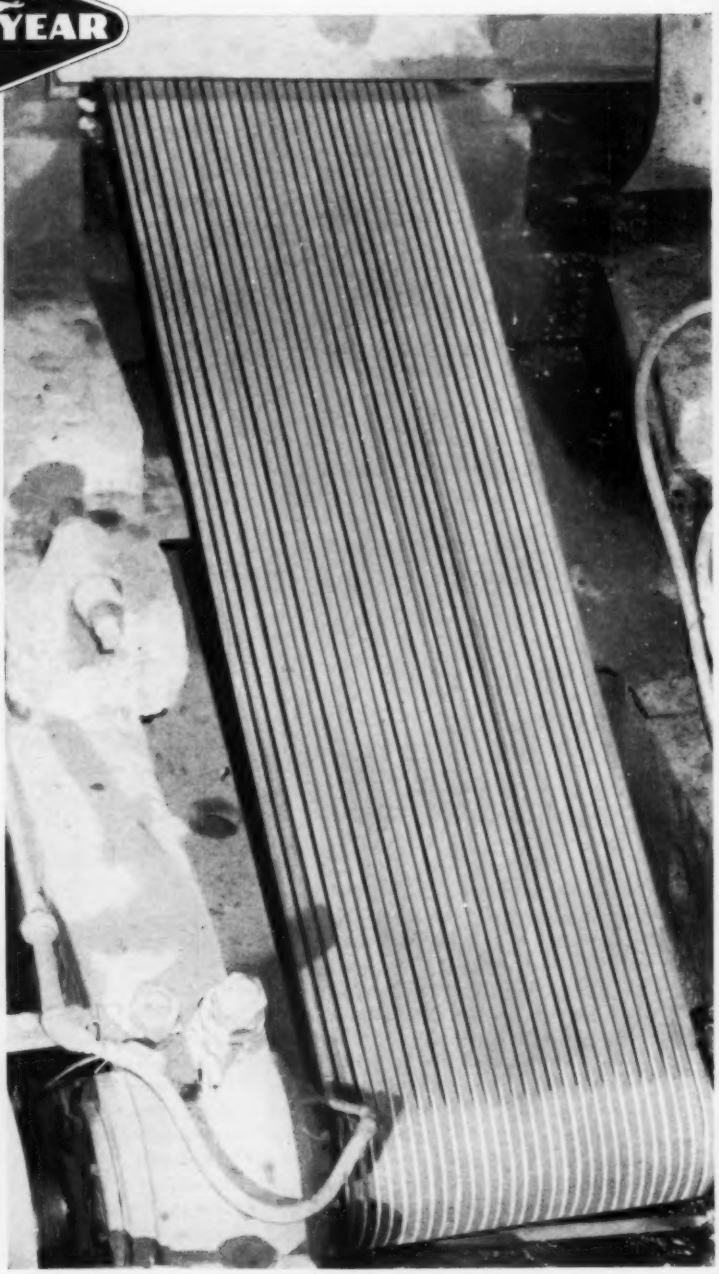
Tiarko Meunier, on the difference in buying habits in France and the US: "French manufacturers of appliances and kitchen cabinets today offer units that match, making up harmonizing installations. But consumers only acquire these units over the years (instalment buying isn't as highly developed here as in the US), and so manufacturers tend not to change designs too often."

GOODYEAR EXCLUSIVE!
IS YOUR SIGN OF V-

GOODYEAR



Goodyear V-Belts' precision matching comes from this exclusive close-tolerance matching equipment that length-codes each belt to 1/32". Most other belt manufacturers code only to 1/10".



Goodyear V-Belts' precision matching assures standout performance. Example: only 28 COMPASS-V-Steel Belts handle this big steel saw, normally calling for 42 belts. Result: the steel mill saved $500 at the original installation – will save more at every belt change.

THE GREEN SEAL BELTS CODED TO 1/32"

Here's your assurance that every belt in a set matches in length–pulls together for maximum trouble-free horsepower hours

What's more, the Green Seal means–

Dimensional stability that lasts the life of the belt–thanks to shrink- and stretch-resistant "muscles" of 3-T Process Cord or airplane-type steel cable built into each belt.

Satisfactory performance even when subjected to dampness – because of special mildew-inhibited compounds.

The most complete line of V-Belts anywhere today – always within easy reach through a nationwide network of distributor stocks.

The proper selection of V-Belts to meet your requirements with the help of the G.T.M.– Goodyear Technical Man – America's top belting specialist.

So make the GREEN SEAL your sign of savings–in both time and money–by calling your Goodyear Distributor. Or write Goodyear, Industrial Products Division, Akron 16, Ohio.

Lots of good things come from

GOODYEAR

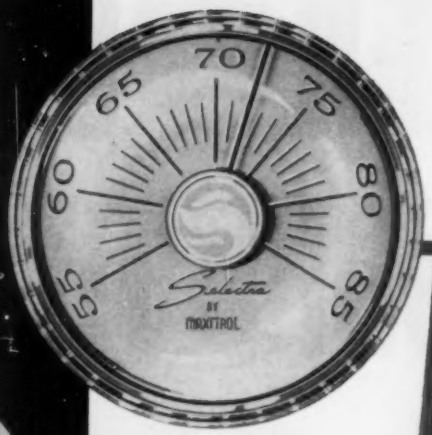
INDUSTRIAL PRODUCTS

Green Seal, Compass–T. M.'s The Goodyear Tire & Rubber Company, Akron, Ohio

CIRCLE 27 ON READER SERVICE CARD

Chace Thermostatic Bimetal

ACTUATES ANOTHER PRECISION PRODUCT ...



MAXITROL

Selectrastat

A PRODUCT OF MAXITROL COMPANY, SOUTHFIELD, MICHIGAN

Maxitrol's "Selectra" system puts an end to cycling of forced air gas furnaces through continuous modulation of the flame. Because the modulation operates electronically, there is no time lag when more or less heat is needed. Inside the Selectrastat, a tiny thermistor no bigger than a pencil lead senses the slightest variation (as little as 1/10 degree) in room temperature. In less than one second it signals a printed circuit amplifier which immediately modulates the flame to provide the necessary heat.

In addition to modulation, the Maxitrol Selectrastat performs a second important control function. The thermistor controls only the modulator valve. In mild or warm weather automatic shut-off action is achieved thermostatically. A Chace Thermostatic Bimetal element performs this function, acting as the upper limit switch.

Maxitrol assures us that the Selectra system will give added convenience, accuracy and dependability. Chace is proud to have its only product—Chace Thermostatic Bimetal—included in such a system. Many manufacturers specify Chace Thermostatic Bimetal because it, too, is famous for dependability . . . a dependability born of more than a third of a century of *specializing* in one product: Precision Thermostatic Bimetal produced to specifications.

Send Now For Our New "Information Booklet"!

It contains many well illustrated pages of valuable design data and examples of successful applications of bimetal! More than 40 types of Chace Thermostatic Bimetal are available in coils, strips and completely fabricated elements of your design.

IT BENDS WITH THE HEAT

W. M. CHACE CO.
Thermostatic Bimetal
1602 BEARD AVE., DETROIT 9, MICH.

READER TO EDITOR

Editorial Kudos

To the Editor:

I read with interest your editorial on p 63 of the Feb 20 issue, "Is Your Morality Showing?" You made a good point. I congratulate you for putting a finger on a principle often neglected or compromised for personal gain.

—J Gordon Knapp
Vice-president
Palma-Knapp Inc
River Forest, Ill

To the Editor:

Your editorial, "The Greater Responsibility," p 35, Feb 13 issue, was excellent and justified. However, you do not say what you are going to do about it, or what I as an individual can do about it.

It is possible that the engineering and scientific groups of the world can do more than most. We have one big advantage in that we have always communicated, or exchanged ideas and progress, in our technical society meetings. We dare to talk across international boundaries, where others cannot or will not. Maybe we could have an international society of technical people who will pick up the challenge that you have portrayed, and whose basic charter will have the specific objective of accepting social and moral responsibility for our achievements.

— T B Holliday
Elmhurst, Ill

Which Glass Is Safest?

To the Editor:

I would like to call your attention to a statement in your Feb 13 issue regarding safety in automobiles. We feel it may be misleading. The reference is contained in a box on p 25 which lists a number of automotive safety suggestions by Dr James L. Goddard, former head of the accident prevention div of the Dept of Health, Education and Welfare.

We believe the statement on "hardened glass" as opposed to "laminated" glass, attributed to Dr Goddard, is telescoped to the point where it appears to exclude from consideration the fact that laminated glass is required by law in all states for the windshields of automobiles, trucks, and buses as a safety precaution. There is considerable evidence that laminated safety glass—that is, a glass sandwich with a plastic interlayer—is the safest material for the glassed-in areas of automobiles. Actually, there is a generally unanimous opinion among safety engineers that laminated safety glass is necessary in windshields; the controversy is over the best protection for side windows.

Generally, laminated safety glass offers these advantages which no other material has:

1. It provides clear unimpaired vision even when cracked. (Tempered glass becomes opaque.)
2. It protects passengers almost completely from road missiles.

3. It gives excellent protection against scattered glass fragments.

4. Its resilience acts as a deterrent to skull fractures in collisions.

In the area of safety performance, there have been extensive arguments between proponents of both types of glass. Since an as-yet unresolved controversy exists on this important matter of safety, we feel the statement in PRODUCT ENGINEERING is an oversimplification that appears to favor overwhelmingly one candidate above the other in all glass areas, including windshields. I am sure this is not the impression the editors wish to create, particularly in view of the fact that the American Standards Association has under technical review the whole matter of glazing materials for automobiles.

—HAROLD G BROWN JR
Public Relations Dept
E I du Pont de Nemours & Co
Wilmington, Del

• There is a basic controversy on windshields between European and American practice. However, there is something to be said for the European glass which seems to craze and powder rather than to crack and shard. We have heard a little of their side of the argument from Europeans, but have never seen definitive test results. The American side of the argument is implied in your four advantages, but we still worry a little bit about the decapitations and jugular cuts that occur when somebody's head goes through the windshield.—EJT

COMING EVENTS

APRIL

19-21 . . . . Institute of Radio Engineers, 13th Annual Southwestern IRE Conference and Electronics Show, Dallas Memorial Auditorium, Dallas.

20-21 . . . . Society of the Plastics Industry, 18th Annual Western Section Conference, Hotel del Coronado, Coronado, Calif.

23-25 . . . . American Society of Mechanical Engineers, Metals Engineering Conference, Penn Sheraton Hotel, Pittsburgh.

MAY

7-11 . . . . American Society of Mechanical Engineers, Engineering Institute of Canada, Hydraulic Conference, Queen Elizabeth Hotel, Montreal.

8-9 . . . . American Society of Mechanical Engineers, Lubrication Symposium, Hotel Deauville, Miami Beach.

8-10 . . . . Institute of Radio Engineers, 13th Annual National Aerospace Electronics Conference, Biltmore & Miami Hotels, Dayton, Ohio.

For a listing of addresses of societies and associations send 25¢ to Product Engineering Reader Service Dept, 330 W 42nd St, NY 36. Ask for brochure R 32.

If you have a tough corrosion problem and need wire cloth or wire cloth parts, here's a source of supply that knows the answers. We are proud of the quality of our cloth...accurate mesh count, close tolerance wire diameter, precision weaving...plus the know-how necessary to specify the proper alloy for your service conditions.

NEWARK for ACCURACY

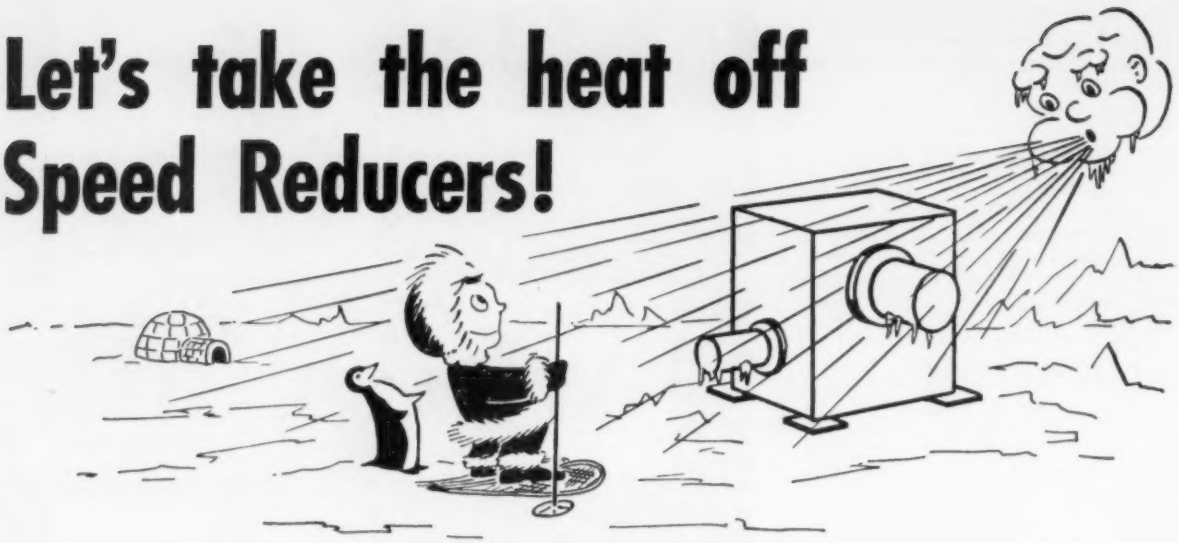
Write or call us today if you have a problem calling for anti-corrosive wire cloth or wire cloth parts. Send for Bulletin F-C.

Newark Wire Cloth COMPANY

351 Verona Avenue • Newark 4, New Jersey

CIRCLE 29 ON READER SERVICE CARD

Let's take the heat off Speed Reducers!



A worm gear speed reducer is one of the toughest little customers in captivity. It reduces speeds day-in, day-out, with little complaint. While it works long and hard, it has limitations—set by ratio, center distance, RPM, mechanical and thermal HP ratings, etc. And, depending upon how precisely it was selected and fitted to the job requirements, it will do what it has to do.

But sometimes it's forced to play outside of its league. It must cope with job requirements that vary from here to there—normal 8 to 10 hour service without recurrent shock, the same length of service where there is some shock loading, continuous low-speed service and almost countless others. But the thing that really puts the pressure on reducers, the thing that's lurking in *every* set of job requirements—is h-e-a-t.

When you exceed the thermal capacity of a reducer for more than an hour or so, excessive temperature thins the lubricant resulting in wear; material, bearing and oil seal failures; etc. Of course, the proper lubricant will help but it can't cure the continuing problem of excessive heat.

So how can we lick this toughy? One way is to build the reducer housing oversize, big enough to radiate the heat away and keep temperatures down. But this type sticks out in aisles, louses up compact designs and barks shins. Then, we might try a smaller housing complete with fins on it to dissipate the heat. If this still doesn't work, another trick is to use a reducer with capacities and ratings a step above the ones we need. This is sending a man to do a boy's job. It's impractical, inefficient and costly. There *has* to be an easier, better, saner and cheaper way to do it. And there is!

In certain cases, where the size and type of reducer permits and where we can gain enough in thermal HP rating to keep heat generation in bounds, Cone-Drive Gears does it with fan-cooling.

What's that? Simple. Just add a fan to the worm shaft plus the necessary air shields, fan cover, etc., and presto!—heat is no longer a problem. The air shields direct the fan-pushed air over the fins on the lower portion of the reducer. The fins are shaped and spotted to guide the air stream where it is needed. Thermal HP ratings are boosted tremendously, as high as 147% above those of standard reducers in some cases! Those over-worked, over-heated reducers will now do the job you bought them to do.

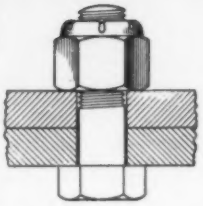
Other advantages? They're here in abundance. The size of the reducer stays the same. All parts on a Cone-Drive fan-cooled reducer are 100% interchangeable with parts for standard reducers. Oil capacity is identical. Shields are quickly removed without disconnecting the reducer. (This is important where severe operating conditions make periodic cleaning necessary). The reducer can also be operated *without* fan-cooling just by taking off the fan and shields.

This simple addition to standard Cone-Drive HU speed reducers might be just your answer—might save you some money. Write for Cone-Drive's Bulletin CD-218. It will tell you all about the full line of Cone-Drive double-enveloping worm gear reducers as well as the fan-cooled kind. Cone-Drive Gears, Div. Michigan Tool Co., 7171 E. McNichols Rd., Detroit 12, Mich.

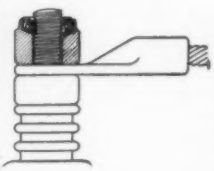
CIRCLE 31 ON READER SERVICE CARD→

Ten fastening problems solved by ELASTIC STOP® nuts

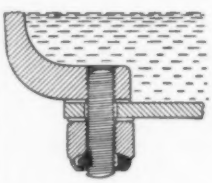
TIGHTENED AGAINST THE WORK



Vibration and impact proof bolted connections in standard applications.

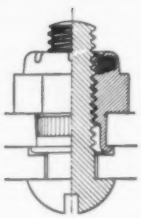


On all electrical terminals subjected to vibration in transit or operation, and for any electrical or electronic assembly where positive contact must be maintained.

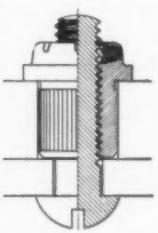


To seal bolt threads where leakage past stud threads must be prevented.

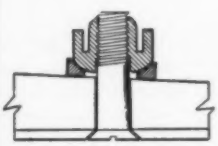
FOR MANY SPECIAL FUNCTIONS



Blind fastening applications where nut is "clinched" into sheet metal . . . becoming self-retaining as well as self-locking.

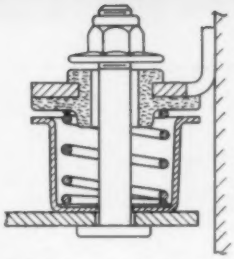


To eliminate drilling and tapping and provide steel thread strength for soft metals, an ESNA spline nut is pressed into a bored hole in casting.

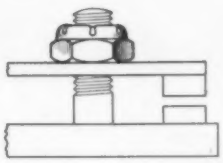


Simplified self-aligning self-locking fastener for bolting two non-parallel surfaces.

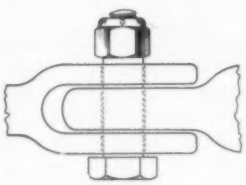
LOCKED ANYWHERE ON THE BOLT



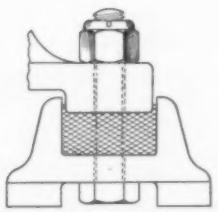
Spring-mounted connections or dynamic balancing, where nut must stay put yet be easily adjusted. (Flanged face eliminates need for extra washers.)



On make and break adjustment studs where accurate contact gaps must be maintained. Note "thin" height design for limited clearance.



For bolted connections requiring predetermined play.



For rubber-insulated and cushion mountings where the nut must not work up or down.

HOW THESE NUTS SOLVE SO MANY FASTENING PROBLEMS, ELIMINATING EXTRA PARTS AND OPERATIONS...

The red locking collar of an ELASTIC STOP® nut grips bolt threads with a perfect fit that will not loosen under severe vibration or stress reversals, and seals against liquid seepage. By bringing nut and bolt metal thread flanks into firm contact it eliminates wear producing axial play. The elastic locking action of the insert-type stop nut does not distort or gall bolt threads. It is reusable many times.

Send for the following free information: Elastic Stop nut bulletin; Rollpin® bulletin. Or enclose a drawing of your product for specific self-locking fastener recommendations. Write to Dept. N30-445.

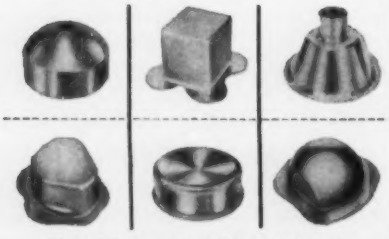
ESNA

ELASTIC STOP NUT CORPORATION OF AMERICA
2330 VAUXHALL ROAD, UNION, NEW JERSEY

KAUPP
PRECISION-FORMED
METAL
COMPONENTS

Hydroforming, Deep Drawing and Spinning

You can depend on KAUPP for complete service from design to delivery on precision-made metal parts and sub-assemblies Ultra modern metal working facilities, plus wide experience on military and commercial requirements are available to solve your problems. Send drawings for quotations or phone for new illustrated bulletins!



Closest tolerances adhered to in all metals, including MU METAL, BRASS, INCONEL, ALUMINUM, COPPER, CARBON STEEL, STAINLESS STEEL, NICKEL, MAGNESIUM, TITANIUM, SILVER, SPECIAL ALLOYS, HAYNES STELLITE.

C. B. KAUPP & SONS

Newark Way, Maplewood, N. J.—POplar 1-4000

METAL CRAFTSMEN SINCE 1924

WHY DON'T THEY R&D..?

. . . plastic knurling for control knobs. These could be made up in a number of stock sizes and prepared so that they would shrink onto a smooth knob with application of moderate heat. Like the "shrink-on" insulators for connectors, the knurled-surface sleeving would first be extruded from a plastic that has a "memory," and then expanded. The consumer need only slip them over a smooth steel or aluminum knob and shrink them into place with heat from a light bulb or the equivalent. —C PERKO

. . . remote detonator for explosives, based on the piezoelectric "spark pump" (see *PE—Oct 24 '60, p 17*). Present detonators are generally of two types: a fuze igniter which slips over the fuze, igniting it with a pull of a wire, and a magneto plunger that sends a pulse of current over a wire to detonate the explosive. Magneto detonators, while allowing remote firing, are bulky, heavy and expensive. A piezoelectric device could be both inexpensive and small—and, because of this, could be made expendable. But it must be capable of generating an instantaneous pulse of current of magnitude sufficient to fire several blasting caps or squibs. —R MARIE

. . . an indicator on the face of oscilloscope tubes that shows speed of sweep, and sensitivity of deflection. This would be very helpful for the many applications in which the oscilloscope trace is photographed for subsequent analysis. Without knowing the scope settings, the trace itself is practically useless. Perhaps the deflection and sweep-frequency control knobs could be geared to drum counters and their images projected on a corner of the screen via a system of mirrors. —L F GARBER

. . . a hydrometer that automatically corrects for temperature of fluid. Hydrometers traditionally include both a thermometer and a correction chart; these are slow, clumsy and likely to induce errors. A better way would be to float the scale on an expanding fluid or gas, thus automatically compensating for temperature change. But the rate of expansion would have to match the rate of change of the correction factor. Also, because correction factor depends on the fluid being measured, the hydrometer would be limited to measuring the specific gravity of only one fluid. But the method would be useful for special-purpose hydrometers such as those used for battery water or antifreeze solution. —J WALLINGER

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A combined reprint

WHY DON'T THEY RESEARCH AND DEVELOP?

A 64-page booklet containing 200 of the best ideas printed in this column over the past 3½ years. From the many suggestions that have appeared, the editors have culled those they believe to be most wanted, most practical in the light of present scientific knowledge. To get your copy of this rich source of new product ideas, send $1 to:

Reader Service Dept, Product Engineering, 330 W 42nd St, New York 36.

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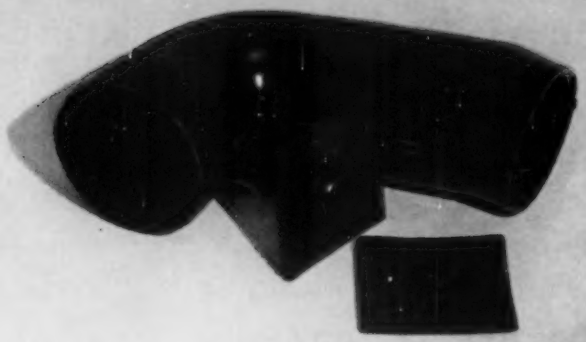
CIRCLE 33 ON READER SERVICE CARD→



Spring Silencers and Heater Duct—MARLEX silencers are durable, self-lubricating, and less costly. Duct is flexible, rot-proof, withstands tears and punctures.

Seat Side Shields—Cost less than painted steel . . . dent and scuff resistant, lighter, easily cleaned, and with "molded in" texture and color.

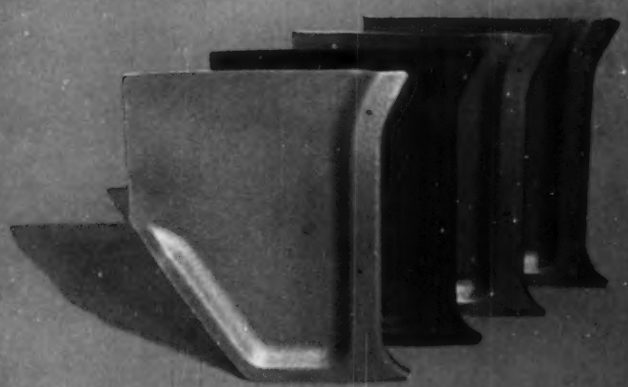
Windshield Washer Jar—Container made of MARLEX won't shatter or burst . . . is unaffected by freezing or under-the-hood temperatures.

The MARLEX* look on 1961 cars

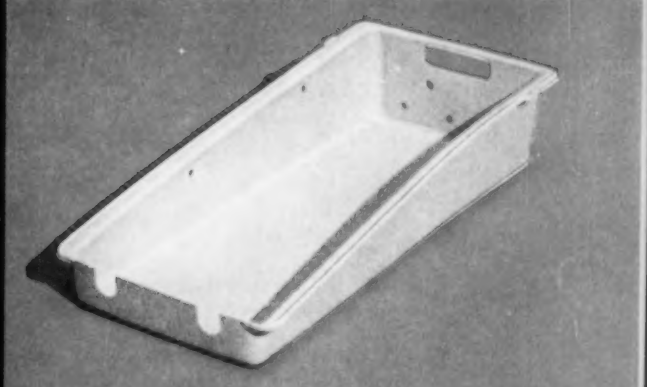
Shown here is a selection of current applications for MARLEX variously used by American Motors, Chrysler Corp., Ford, and GM. They offer new proof of the improved performance (at comparable or lower costs) provided by this versatile, high density plastic.

MARLEX items (like the original equipment applications shown here) are unaffected by extremes of temperature (—180°F to 250°F) and resistant to acids, alkalies, oil and grease. They are lightweight, tough, durable, non-allergenic, corrosion- and rot-proof . . . can be machined, welded, bolted, and printed upon. There are production advantages, too. Superior finished items can be quickly and economically produced from MARLEX high density resins by injection molding, extrusion, blow molding or thermoforming.

Technical and design data on MARLEX high density polyethylenes and ethylene copolymers, and their many uses, is available to you.



Side Cowl Panels—Colorful and textured MARLEX panels improve styling . . . will not scuff, dent, or tear . . . are color fast and easily cleaned.



Glove Compartment—Economical "quality upgrading" with MARLEX . . . new box is rugged, functional, and longer lasting.

*MARLEX is a trademark for Phillips family of olefin polymers.

For more information, see your plastic fabricator . . . or contact us.

PHILLIPS CHEMICAL COMPANY
Bartlesville, Oklahoma
A subsidiary of Phillips Petroleum Company

PHILLIPS 66 MARLEX POLYMERS

TO INSURE SUCCESSFUL PERFORMANCE

EVERY GRAMIX® PART IS

(PRODUCTS OF POWDER METALLURGY)

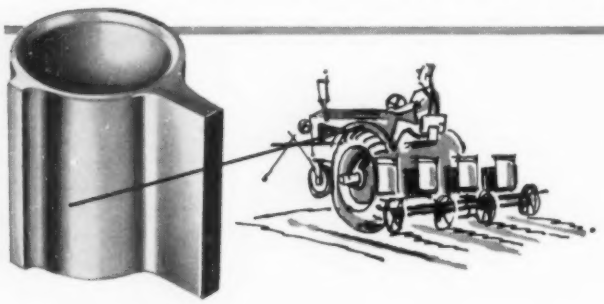
APPLICATION ENGINEERED

One of the most important factors to consider when purchasing powder metal parts is that of successful part performance; for a part to successfully perform its job, all of its physical and metallurgical characteristics must be suited to the application.

GRAMIX Products of Powder Metallurgy are always *Application Engineered,* which means product is specially matched to each specific application. From an almost unlimited variety of metal mixtures, one alloy is blended that contains the required properties and characteristics of the finished part; *all* aspects of part design and conditions under which it must operate are taken into account. Only then is the GRAMIX part produced.

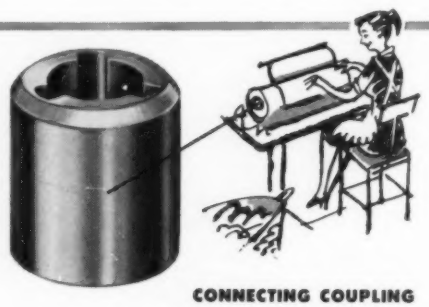
Eight of these *Application Engineered* GRAMIX parts are shown here. Each precisely suits the requirements of its job . . . each is the best part available for the job.

When you specify a GRAMIX part, you can always be sure that it has been *Application Engineered* for successful performance, long life and complete reliability. For more information on *Application Engineered* GRAMIX parts, write for Engineering Handbook G-55.



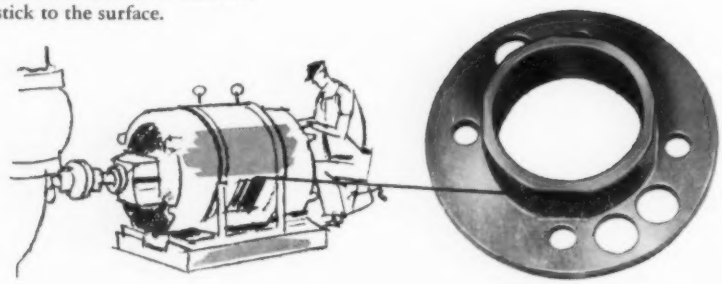
CORN SEEDER

GRAMIX was the material specified for this corn seeder part because the surface finish obtainable with the alloy used reduced the tendency of material to stick to the surface.



CONNECTING COUPLING

The connecting coupling employed in a small home ironer is formed from a special GRAMIX hardened steel alloy; it offers low wear and shock resistance.



CONTAINER COVER END CAP

Great savings were realized when retainer caps for certain types of electric motors were made of GRAMIX.

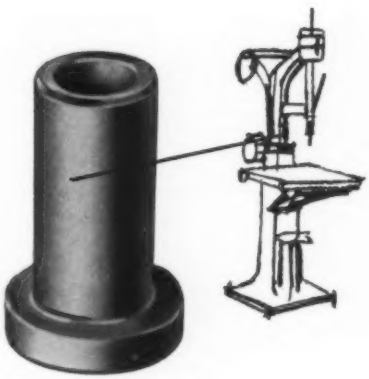
This process made it simple and economical to mold the multiple holes to precise tolerances without extra operations.

HELICOPTER THRUST WASHER

The outstanding features of the GRAMIX alloy specified for this thrust washer are a dependable and consistent friction and wear pattern as well as a fine surface finish.

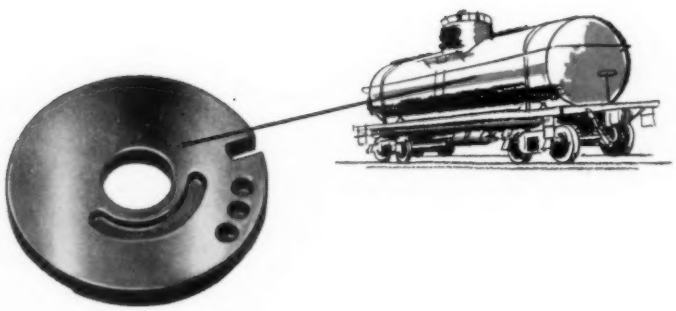
TAPE RECORDER SPINDLE

One of the important requisites in a tape recorder is a low noise level. United States Graphite Company engineers developed a special alloy to meet these requirements in the GRAMIX spindle.



GUIDE BEARING

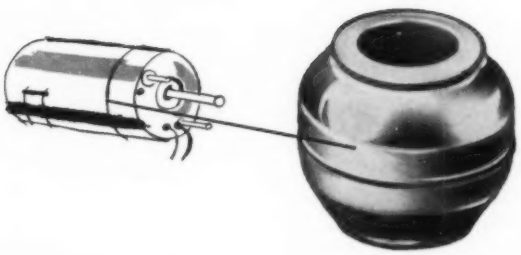
Built-in lubrication and low friction to reduce heat are important features of the GRAMIX alloy chosen for this guide bearing.



LIQUID PUMP END PLATE

This end plate is typical of many parts employed in liquid pumps of many types.

It is made from a wear resistant bronze alloy that was developed for pump applications.



FRACTIONAL H.P. MOTOR

The GRAMIX bearing for this Fractional h.p. motor was developed from a special low noise level alloy.

Its self-lubricating properties were also an important consideration in specifying GRAMIX.

METAL POWDER mpi INDUSTRIES FEDERATION

X-296-2

THE UNITED STATES GRAPHITE COMPANY

DIVISION OF THE WICKES CORPORATION, SAGINAW 1, MICHIGAN

GRAPHITAR® CARBON-GRAPHITE • GRAMIX® POWDER METALLURGY • MEXICAN® GRAPHITE PRODUCTS • USG® BRUSHES

THE PROPER USE OF SPECIFICATIONS

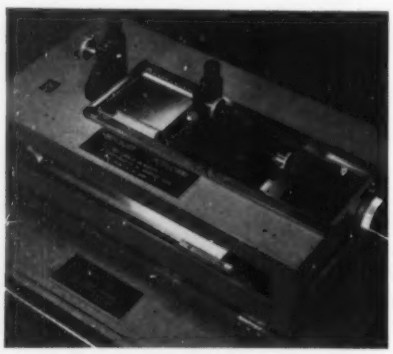
Specification testing is useful as a method of quality control. But specifications alone do not form a sound basis for gasket selection or predicting gasket performance, since performance is determined by the interaction of many factors.

EDISON POWERS
Armstrong Research and Development Center

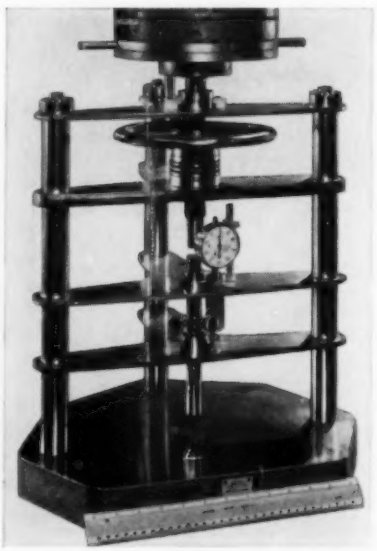
A resilient gasket material that meets all pertinent government and industry specifications may still fail to provide a satisfactory seal in actual service. At the same time, a material that falls short of one particular specification may well be the most suitable for a certain application.

The reason for this is that gasket performance is determined by many factors—such as flange pressure, contained fluid, qualities of the material—in infinite combinations. It is impossible to set up tests which will take all the combinations of these factors into consideration.

As a result, specifications frequently do not give a realistic idea of the gasket's performance. For instance, many gasket specifications have rigid tensile strength requirements. Tensile strength is easily measured. Yet it usually has little bearing on the sealing ability of a material. For all practical purposes a gasket needs only sufficient tensile strength to hold its shape until it goes to work in the flange.



This Armstrong-developed instrument—called a dilatometer—is used to study dimensional changes in gasket materials caused by different conditions of temperature and humidity. It can detect variations as small as half a mil in a 12" sheet.



This device is used by many laboratories to help standardize gasket testing. Developed by Armstrong and recognized by the National Bureau of Standards, it is used to measure indentation and recovery characteristics of resilient gasketing materials.

Tests for resistance to liquids are also unrealistic where uncompressed strips of gasket materials are completely immersed in various fluids. Test results may show intolerable changes in such factors as volume, compressibility, recovery, and elongation. In practice, however, only the edge of the gasket is exposed, and the effect of the fluid may be negligible.

Other tests—ream weight and bursting strength, for example—have been taken from the paper industry. Again they are of little help to gasket users in selecting materials.

Compounding the difficulties of selection by specification is the lack of standardization in test procedures and instruments. In the matter of compressibility alone, there are the variables of sample size and type of pressure foot, and the method and speed of load application.

Another difficulty with the practice of buying gaskets by specification is the fact that it may delay the discovery and use of new materials that will do the job better. Unless specifications are frequently reviewed, they are likely to be outdated.

Gasketing efficiency can be improved by asking the question, "Will it do the job better?", when you select a material rather than, "Does it meet our specifications?" Once you have selected the proper material, you can establish new specifications and then put specification testing to its proper use—as a means of quality control to make sure that each succeeding shipment of gasket material has the same physical and chemical characteristics.

The Armstrong Gasket Design Manual offers a wealth of research material on gasket design and selection. If you would like help in selecting a gasket material or establishing new specifications or a copy of the manual, write Armstrong Cork Company, Industrial Division, 7104 Irvin Street, Lancaster, Pennsylvania.

Armstrong GASKET MATERIALS

Allis-Chalmers combines fend off corrosion . . .

GUARDED BY GALVANIZED STEEL

When you see a big Allis-Chalmers combine like this cutting grain on the farmlands of America you can be sure that galvanized steel has been used in its construction.

Reasons? First, galvanized steel provides excellent weather protection and low maintenance cost. Neither dew nor drizzle nor drenching rain will find a chink in its zinc coating. That holds true regardless of the severity of the fabricating steps to which it may be subjected. And in addition to its corrosion resistance, galvanized steel has a lot of resistance to high cost: It's easy and economical to fabricate, construct and maintain.

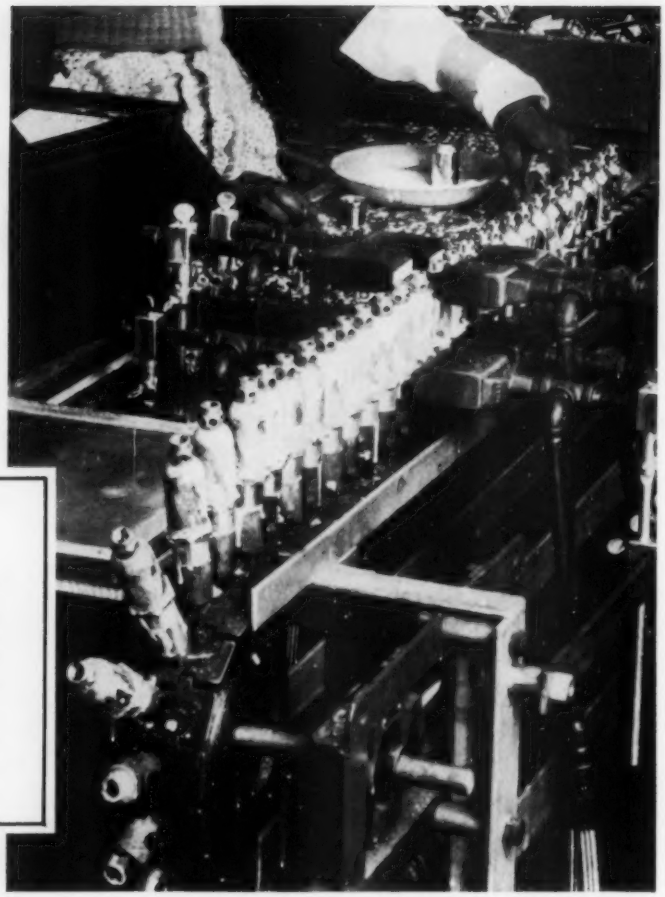
WEIRKOTE® IN PARTICULAR! The galvanized steel used in these combines is National Steel's Weirkote. To the inherent strength, economy and versatility of steel, Weirkote adds enduring zinc protection via the modern continuous process. As a result, Weirkote can be worked to the very limits of the steel base without chipping or peeling. And it assures you of long-lasting protection against corrosion. It is manufactured by two National Steel Corporation divisions, Weirton Steel and Midwest Steel. Write Weirton Steel Company, Weirton, West Virginia, for further details.

MIDWEST STEEL
Portage, Indiana

WEIRTON STEEL
Weirton, West Virginia

divisions of
NATIONAL STEEL CORPORATION

CIRCLE 37 ON READER SERVICE CARD



Operator dips parts in HANDY FLUX and assembles them with EASY-FLO 45 rings on a moving rig. Assemblies then pass between banks of gas burners to complete brazing process. Capillary action of EASY-FLO brazing alloy insures thorough penetration—guarantees high strength, leakproof joints.

Flair No. 21 Hot Water Air Vent consists of the basic free-venting air valve, a generous air-collection chamber and a massive hex base. Two preform rings of EASY-FLO 45 are used in the brazing operation. Valve assembly at left was subjected to extreme pressure. Note how body ballooned; joints strong and leaktight.

How Flair Manufacturing Speeds Production, Eliminates Costly Casting With Easy-Flo Brazing

Never a field failure in any joint brazed with EASY-FLO 45 and HANDY FLUX—that's the proud record of Flair Manufacturing Company, Brooklyn, New York, makers of an extensive line of air valves and other specialties for steam and hot-water systems.

Flair finds that brazing with EASY-FLO 45 offers competitive advantages in every aspect of design, production economy and service life. Big savings are made through elimination of costly casting equipment and more productive use of space. Production is smoother, faster. Valves look better, last longer... in tests to 5000 psi, valve bodies burst while brazed joints remain intact. All this for an alloy cost per unit of approximately 2½¢ for two preform rings of EASY-FLO 45.

Speed, strength, economy, low labor costs—advantages *any* manufacturer would be glad to have. And, all achieved through use of Handy & Harman silver alloy brazing. Chances are silver alloy brazing could benefit your product too. If it could, or if you think it *might*, don't hesitate to get in touch with Handy & Harman. We'll help you in every way possible. Why not call us today?

DON'T MISS OUT . . .
on Handy & Harman's new silver alloy brazing Correspondence Course. Designed to put *all* the facts and techniques at your fingertips, this course is invaluable to everyone concerned with silver alloy brazing. Send for "Training Course Prospectus."

Your No. 1 Source of Supply and Authority on Brazing Alloys

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PRODUCT ENGINEERING HORIZONS

April 17, 1961

STONE UPON STONE

The temples of Greece and of the Mayans, the cathedrals of Europe—all the monuments of the Old World—have been built painstakingly by laying stone upon stone. The older ones are built without mortar, which meant days of work to fit and interlock each block. Some structures took centuries to build, while generations lived and died. The ideas and plans of the original architect in many cases died with him, but the building went on. Those who worked on it had no hope of seeing it completed, but felt their sons or grandsons might. And this was enough; they were content. The future was clear; their sons and their sons' sons would live as they had lived.

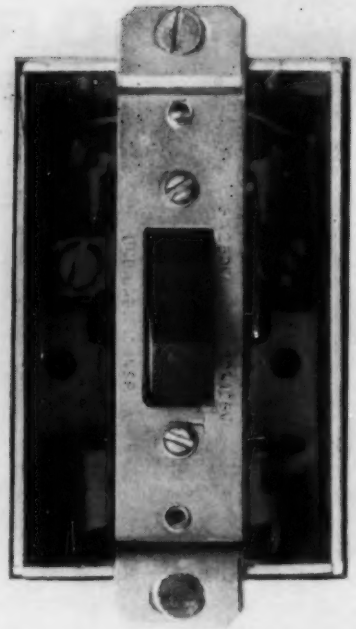
The reputations of families and of businesses were similarly built—by painstakingly laying stone upon stone, through the generations. There were no shortcuts.

Even in our foreshortened Age of Acceleration, the cycle of development follows the same pattern in an impatient sort of way. In the chemical industry, they speak of a development cycle of seven years "from test tube to tank car." Studies of mechanical developments show similar patterns of five to seven years.

But, in that time, personnel on the project may be changed radically. Ordinary turnover rates of 10% per year may result in half or more new people on the project, and our practice of multi-step development by specialists may have even more drastic effects. The original concept of the inventor may be radically changed by other men's ideas, by roadblocks, by economic cycles, by the fairly vicious limitations of the annual budget, by customer whims.

Someone said long ago, "Rome wasn't built in a day." Neither is anything today. It must be the product of one man's mind, implemented by many minds, many hands, and time, just as it always was. But the rules have changed. No longer is there any reason to assume that the future will be like today. Conditions change too rapidly. Thus time can erase direction, and the original idea may be lost in changes to meet current conditions.

To put it another way, the telescoping of the time period during which a product can be sold places new demands upon the developer. He must be certain his design anticipates change. He can't design a "cathedral" in the belief that it will be built by, and suit, succeeding generations as well as his own, because a technological civilization won't stand still for six centuries of Gothic towers. And his design, or his personality, must be strong enough to preserve the concept or idea so his successors know and retain the full depth and breadth of his idea; otherwise, each "generation" (or development design) will depart further from the inspiration until the product is an uninspired dud.



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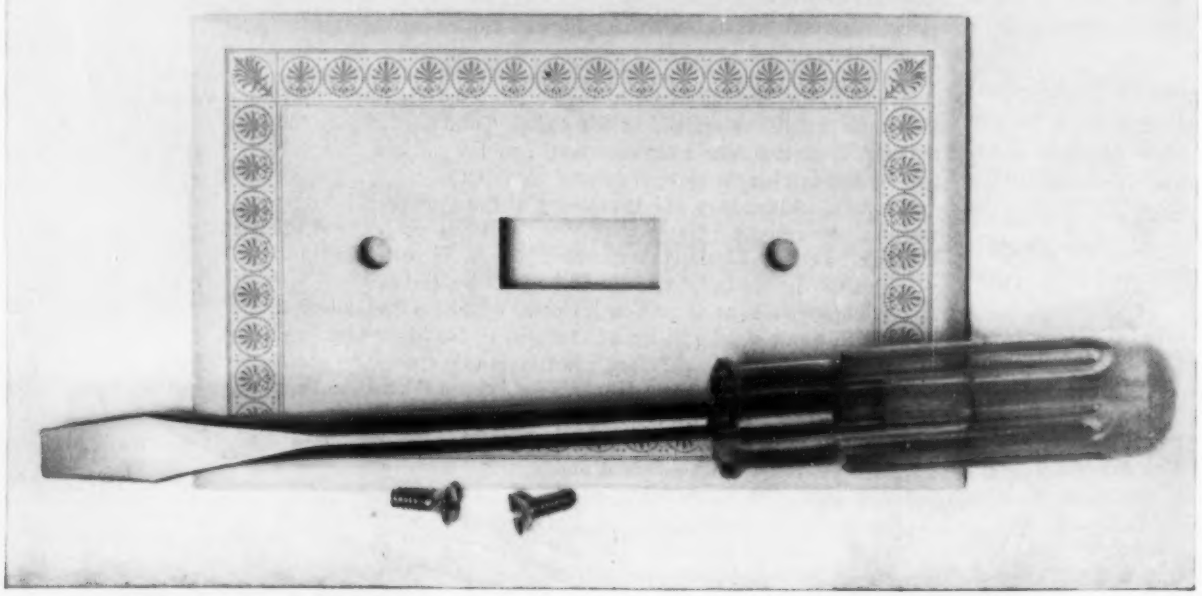


PRODUCT ENGINEERING

how to pick

THE RIGHT MECHANICAL COUNTER

Don't rely on a last-minute choice from a catalog.
Instead, design the entire system with the counter in mind.
Here are the rules to follow.

L D TEMPLE, *Bowmar Instrument Corp, Fort Wayne, Ind*

Mechanical counters might seem to be simple, but they can pose tricky design problems, particularly in systems where both speed and service life are critical. The counting rates required by most machines today make it necessary to design the counter directly into the system. No longer is it practical to choose a completely satisfactory part by catalog number.

FOR A BETTER DESIGN

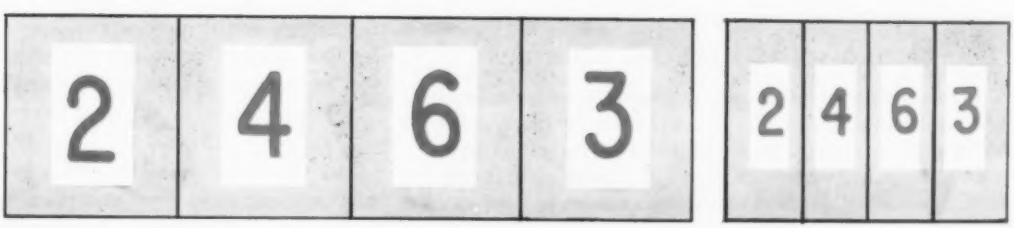
If a counter is improperly incorporated in a system, it can be the weak link. But it won't be if you remember these points.

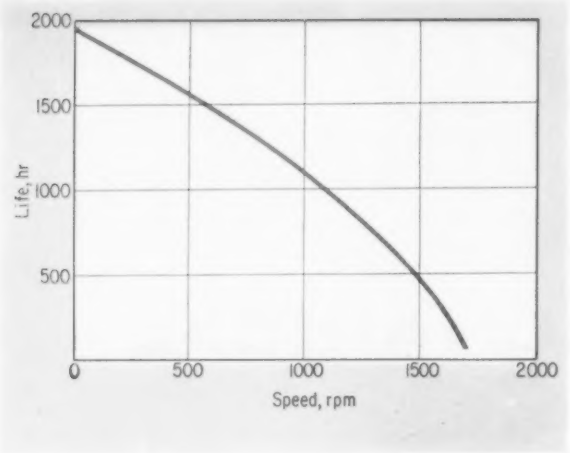
Hold counter-wheel diameter to a minimum

Don't tie down character height too soon Character height determines wheel diameter, and the wheels represent most of a counter's inertia. A rigid specification of this dimension can hamper you in more important areas—speed, torque, and life.

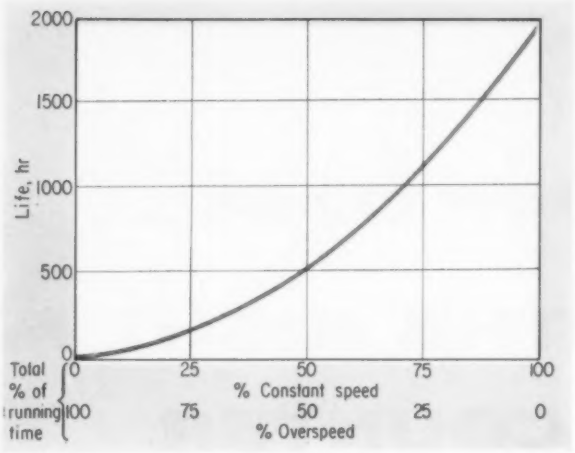
Character height is only one factor involved in readability: The three- or four-digit number registered on the average counter must be read as a unit; and at a distance of two or three feet. For example, a four-digit counter with ¼-in. numerals on wheels spaced 0.500 in. from center to center is not significantly easier to read than one with ⅛-in. numerals on wheels spaced 0.190 in. from center to center. The wider spacing of the larger characters makes it difficult to comprehend the counter readout at a glance. (See sketch below, drawn twice actual size.)

continued, next page





USE LOWEST SPEED POSSIBLE—importance of this is seen in typical life-speed curve.



TYPICAL LIFE under variable operating conditions shows importance of constant speed.

Hold counter speed to a minimum

Inertia increases with the square of the velocity, so life drops off rapidly as speed increases. A typical life-speed curve is above, at left. The precise curve for a given unit will depend on the number and size of the counter-wheels and upon the type of transfer mechanism, but it will not differ significantly from this basic curve.

If you run into a snag, reexamine your demand for accuracy. Does your system really require a full count in the last decade? What would you lose by rounding that last place off by fives? Counters with 10 units per drum are available with the input wheel marked *0,5,0,5,0,* etc., but with all wheels to the left marked conventionally from 0 through 9. Such counters advance the readout by 500 in only ten revolutions, transferring at each zero: a unit running a full count on the input wheel requires 50 revolutions to achieve the same result even though the counting rate is not any faster. If the system permits these looser limits, you can reduce counter speed by a factor of 10 and raise the available torque by increasing the ratio from the driving source. At the same time, you cut down the running-torque requirements and increase counter life.

Maintain a steady speed

The life of the counter is also limited by its duty cycle—that is, by the time it is operated at maximum rated constant speed against the time it is operated at overspeed. A typical curve for this relationship is shown above, at right. The precise shape of the curve for a given system depends primarily on the two speeds involved and the differential between them. But as was the case with life vs speed, the actual curves will not differ greatly from the basic one.

DRIVING SOURCES FOR THE COUNTER

If the driving source is handcrank or some other manual control, avoid step-up ratios over 5:1 from the drive to the counter input. If you must employ a higher ratio, apply a drag brake to the counter shaft. Without such protection, momentary speeds of over 2000 rpm can be produced by twirling a ½-in.-dia knob driving through a 6:1 step-up. There is also the danger that an abrupt reversal of direction will whiplash the wheels, and perhaps pound out the locking cams and transfer pinions.

If the driving source for the system is a servomotor, the torque available at the counter, and the inertia reflected back to the motor are of primary concern, particularly in systems where response is critical. In this area, work closely with the supplier, since acceleration (response speed) can be specified realistically only in terms of a specified input torque. And the counter's torque requirements involve close calculation of the inertia to be overcome.

Torque requirements must be considered under both static and running conditions over the entire temperature range. You must have power available to start the unit and sufficient additional power to meet the maximum required input speed. Running torque—the sum of friction and transfer—is seldom a major problem at normal temperatures. In extreme cold, however, lubricants in some counters tend to "set up." Such an increase in viscosity will increase input-torque requirements. Therefore lubricants must be used that will operate at low temperatures, yet not evaporate at high temperatures.

INERTIA AND TORQUE CALCULATIONS

The precise calculation of inertia is complicated; it involves exact dimensions and weights of a number of parts—counter-wheels, full-tooth gears, locking cams, two-tooth transfer mechanisms, pinions, and shades. This calculation should be done by the supplier, but you should be familiar with the basic problems involved.

The inertia of a straight decimal counter can be approximated (somewhat roughly) by grouping the wheels, gearing and pinions as separate cylinders and figuring their inertia as three separate pieces, using this equation:

$$I = 1/2\ Mr^2$$

where

$$M = \frac{k\ V}{g}$$

and where k is the weight of the cylinder in pounds per

cubic inch (0.102 for aluminum wheels, 0.289 for steel gearing and pinions and V is volume in cubic inches.

The sum of the three calculations is an approximation of the total inertia of the counter with all wheels transferring simultaneously from a static condition. In actuality, of course, this maximum inertia will be met only occasionally. For a three-drum, single-width wheel decimal counter, for example, one-third of the total can be assigned to each wheel assembly. Load applied to the driving source will be only a third of the total when the input wheel alone is started. It rises to two-thirds at the transfer point, where the middle wheel starts as well.

Since transfers are complete in about 36° of arc in most counters with standard mechanisms, the probabilities are 9 in 10 that only the inertia of the input wheel will be encountered at any starting point selected at random. In a three-wheel unit, this figure will be doubled or tripled in the transfer area, depending upon the number of wheels transferring.

Additional problems arise under acceleration. Driving torque, if plotted, would show sharp peaks at each transfer point, since wheels at rest tend to remain at rest. The amplitude of these peaks depends upon the number of wheels engaged in the transfer. The torque required to overcome the inertia of the wheel assemblies is:

$$T = \frac{J\ (\omega_1 - \omega_2)}{gt}$$

where T is torque in lb-ft, J is the moment of inertia, lb-ft², for all wheels transferring, $(\omega_1 - \omega_2)$ is the change in angular velocity in radians per second, t is time in seconds to make speed change, and g is acceleration of gravity.

The periodic peaks created in the torque curve tend to set up vibrations as the speed increases. If the speed is high enough, these vibrations can create problems. Furthermore, the changing load conditions on the counter's gear train can produce a destructive hammering effect, especially if gear faces are too small to handle the impacting force. Locking cams and pinions can also be damaged, and —if the torque is high enough—the pinion shaft itself can be deflected sufficiently to jam the wheels.

Suppliers make provisions to counteract these problems. Some incorporate special transfer devices in units designed for high-speed operation. The Geneva mechanism, for example, can be adapted for this purpose. It has definite drawbacks, however, because of its sliding friction; it wears rather rapidly, and it tends to introduce ambiguity into the readout at the transfer points.

Another approach is to build the counter so that its reflected inertia is great enough, in proportion to its driving inertia, to cause a slight, but significant, reduction of speed at the point of transfer. Since torque is inversely proportional to time, the retarded transfer reduces the torque load and increases the life of the gear train.

If you keep all these considerations in mind, you can write a realistic specification for a counter. If you draw your specification well—keeping it as complete as possible, without making it self-defeatingly rigid—you can take advantage of the specialized experience and capabilities of your suppliers. In most cases, it is best to state your problem fully in your first inquiry. Use the following checklist as a guide.

HOW TO SPECIFY

- **Driving source (servomotor? mechanical? other? describe)**
- **Maximum continuous speed required**
- **Maximum intermittent speed required**
- **Duty cycle at these speeds**
- **Temperature range**
- **Minimum torque available over temperature range**
- **Maximum allowable inertia reflected at driving source**
- **Required life**
- **Counting rate and accuracy of readout**
- **Distance and angle at which counter is to be read**
- **Minimum and maximum numeral size acceptable**
- **Special environmental considerations.**

EDITOR'S NOTE: Counters, digital displays and related design problems have been treated in these previous articles:

Digital Readouts, Oct 31 '60, p 46. Complete roundup of all types of digital displays, how they work, how to choose the right one.

The Significance of Wk² and How to Calculate It, June 27 '60, p 39. Discusses the importance of external inertia referred to motor shaft, describes how to calculate Wk², provides table of gear-train and equivalent inertias, table of inertia values for solid-steel cylinders 1 in. long in diameters from 1 to 200 in., and gives approximations for moments of inertia of various parts: flywheels, gears, armatures.

Selecting Counters for Digital Display, May 16 '60, p 106. Author gives specific suggestions on counter type, speed, driving torque and life—and a case history.

—Frank Hall

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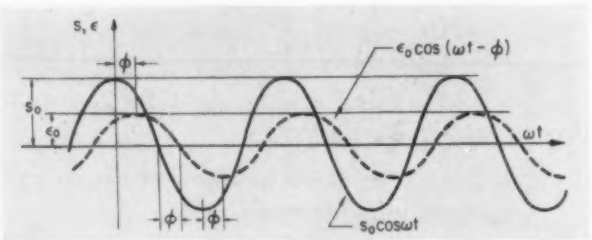
Your selection guide to

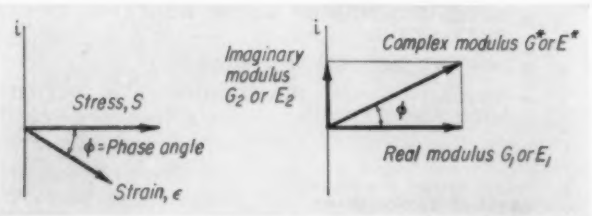
HIGH-DAMPING MATERIALS

ERIC E UNGAR, *senior engineering scientist*
Bolt, Beranek and Newman Inc, Cambridge, Mass

D KENT HATCH, *product engineer*
Plastics Division, Monsanto Chemical Co, Springfield, Mass

To control vibration in structures by applying viscoelastic materials, you must first know their dynamic mechanical properties and how they vary. The authors have searched dozens of sources to bring you basic data on over 50 important materials, and have coupled this data catalog with an introduction to viscoelastic damping. Sample problems show how to put theory and data to work.





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Suppose you are designing a mechanical system that will have to operate in a vibration-laden environment. You can avoid structural fatigue by keeping the natural frequencies of the system well away from the exciting frequencies. This is done by adjusting stiffness and mass factors in the structure itself or, where that is impossible, by adding protective devices that either absorb the excess energy or transfer it away.

But what do you do when the frequency range of possible excitation is so wide that resonances cannot be avoided by these protective means? This is a growing problem, because of the rapidly increasing sources of intense excitation that have wide-band frequency characteristics.

Built-in damping is one answer now receiving increasing attention. Rubbers and plastics that can dissipate large amounts of energy, when stretched or sheared, are being added to vibrating metal structures as a simple, cheap, lightweight, yet effective way of controlling resonance problems. These "viscoelastic" materials can be added in many forms: complete or partial coatings, inserts within structural members, laminations, tapes, or vibration mounts of new design.

Behavior of such materials is complex, and importantly affected by temperature and by frequency of vibration. Besides providing a simple introduction to viscoelastic materials, this article includes a materials catalog containing dynamic mechanical-property data for over 50 materials suitable for damping applications, and sample problems that illustrate how to match the material to the application.

WHAT ARE VISCOELASTICS?

Hooke's famous law "stress is proportional to strain" is the basis of most structural design. An ideal elastic material obeys Hooke's law **independently** of rate of loading. Most metals are nearly ideally elastic, up to certain stress levels, for most commonly encountered loading rates and temperatures. On the other hand, the stresses in ideally viscous fluids are **proportional** to rate of strain, regardless of the stress level.

1 . . STRAIN LAGS STRESS in a viscoelastic material by a phase angle ϕ. Tangent of this angle is β, the loss factor for the material. Here, sinusoidal loading is assumed.

2 . . DYNAMIC MECHANICAL PROPERTIES in the complex plane are more easily visualized. Left: the stress-strain vector diagram, with strain ϵ lagging stress S by phase angle ϕ. Right: the vector relation between real modulus E_1 or G_1, imaginary modulus E_2 or G_2, and complex dynamic modulus E^* or G^*. For viscoelastic materials, values of G are about one-third those of E.

In most cases, design may neglect the effects of loading rate for metals, and the effects of stress level for fluids. For most materials, however, there is a range of temperatures and loading rates within which stress effects and strain-rate effects are of equal importance. In that range the materials are said to be viscoelastic. Most of the rubbers and plastics in use today act viscoelastically to some degree at commonly encountered temperatures and loading rates.

As their name implies, viscoelastic materials possess combinations, in various proportions, of energy storage (elastic) and energy-dissipation (viscous) capabilities. They are therefore well suited to applications where such combinations are required. Present-day uses of these materials fit into two rough classifications, depending on which of the two energy terms dominates. For example, energy storage is more important for tires (it gives them their springiness); energy dissipation contributes to the riding quality in a lesser way by reducing vibration and wave effects in the tire. On the other hand, the materials utilized in vibration- and sound-damping systems are selected primarily for their energy-dissipation properties. This article concerns mainly the behavior of materials in the second category.

WHAT QUANTITIES CHARACTERIZE THEM?

If a small sinusoidal stress, $s = s_o \cos \omega t$, is applied to a steel rod, we observe a strain equal to $\epsilon_o \cos \omega t$, which "follows the stress" exactly, so that ratio of stress to strain (Young's modulus) is independent of time. However, if a similar sinusoidal stress is applied to a viscoelastic material such as natural rubber, one observes a "delay" or "lag" in the strain. This delay comes from the viscous behavior. The strain now is of the form, $\epsilon = \epsilon_o \cos (\omega t - \phi)$, where ϕ may be called the "angle of lag" or the "phase angle between stress and strain."

This lag may be visualized from Fig 1. The ratio of stress to strain is a function of time here and a single number can no longer suffice to describe behavior of the material. However, if ϕ (or some function of ϕ) is specified in addition to the ratio of peak stress to peak strain, a diagram like Fig 1 may be constructed for given conditions. Thus these two quantities can be used to establish the required relation between stress and strain.

For sinusoidally oscillating systems it is usually convenient to: (1) use complex notation (replacing $\cos \omega t$ by the real part of $e^{i\omega t}$); (2) perform calculations in the complex domain; and (3) use only the real part of all time-dependent complex quantities to obtain the final results. This scheme has the advantage of algebraic simplicity and of permitting simple representation of certain quantities as complex numbers. For example, for a stress of $s = s_o e^{i\omega t}$ and strain $\epsilon = \epsilon_o e^{i(\omega t - \phi)}$ corresponding to the previous discussion, a complex Young's modulus may now be defined.

$$E^* = s/\epsilon = e^{i\phi} s_o/\epsilon_o. \qquad (1)$$

Of course, E^* is a complex number and may be written in terms of a real part E_1 (the storage modulus) and an imaginary part E_2 (the loss modulus),

$$E^* = E_1 + iE_2 = E_1 (1 + i\beta) \qquad (2)$$

where

$$\beta = E_2/E_1 = \tan \phi \qquad (3)$$

is called the "loss factor associated with Young's modulus". The term "loss factor" is used because it can be shown that energy losses are closely related to β.

The loss factor β of a material is a direct measure of its energy dissipation or vibration-damping capacity. For a bar made of a single material, this loss factor is related to the quality factor Q, the resonance amplification factor A_r, the logarithmic decrement δ, and to the ratio c/c_o of damping to critical viscous damping of the bar (in absence of external energy losses) as follows

$$\beta = 1/Q = 1/A_r = \delta/\pi = 2c/c_o \qquad (4)$$

when β is not too large. Somewhat more complicated expressions apply for a large β (say, $\beta > 0.3$).

Although normal stresses were implied in the previous discussion, shear stresses might have been used as well. For these, one similarly obtains a complex shear modulus

$$G^* = G_1 + iG_2 = G_1 (1 + i\beta) \qquad (5)$$

The interrelation of these various quantities in the complex plane is shown in Fig 2.

A rough comparison of the dynamic elastic properties of various groups of common structural materials appears in Table I. The wide range of properties for rubbers and plastics makes these materials a logical source for energy-dissipation applications. Width of the properties range is due only partly to the wide choice of available materials; the variation of properties of a single material with frequency and temperature also accounts for a considerable portion of this range—as is shown below.

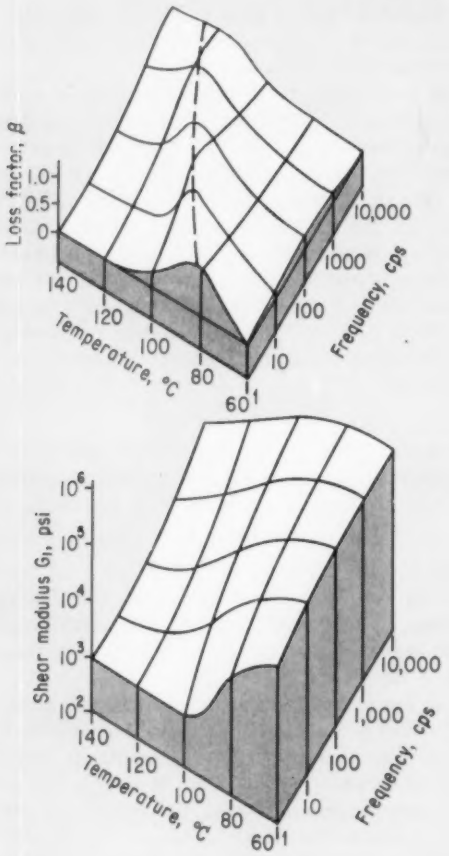
I—DYNAMIC MECHANICAL-PROPERTY RANGES FOR SOME COMMON STRUCTURAL MATERIALS

Material	Loss factor	Tensile Modulus E_1 psi x 10^6
Metals	0.0001 to 0.001	5.0 to 35.0
Glass	0.001 to 0.005	8.0 to 12.0
Concrete, bricks	0.001 to 0.01	1.0 to 10.0
Sand, granular media	0.01 to 0.05	0.1 to 3.0
Wood, cork, plywood	0.01 to 0.20	0.5 to 2.5
Rubbers, plastics	0.001 to 10.0	0.000,01 to 0.5

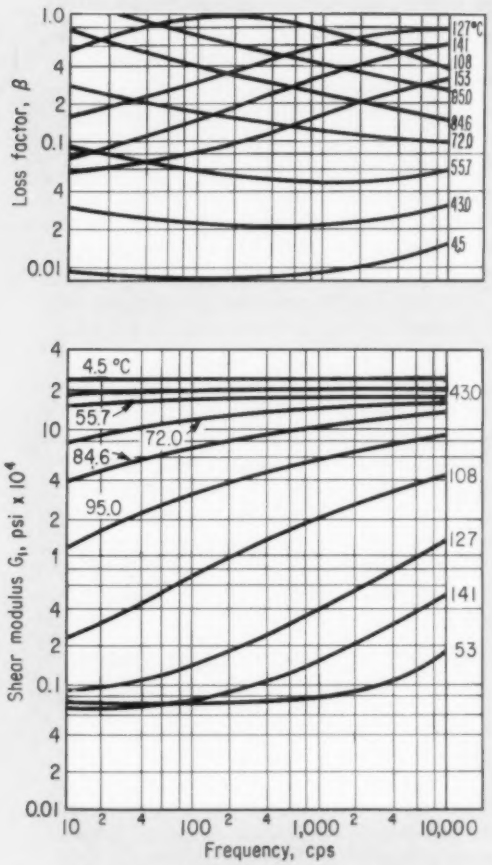
HOW DO THEY BEHAVE?

It's logical to expect the dynamic properties of materials in general, and of viscoelastic materials in particular, to depend on a number of variables: fre-

Two methods of displaying dynamic mechanical-property data



3 . . ISOMETRIC GRAPHS, like these for a polyester plastic (material No. 9 in Table II, p 54), give a good feel for variations of loss factor β and modulus G_1 with temperature and frequency, and how changes in material content would shift properties. Main drawbacks: values cannot be easily read from 3-D plots, and usually data are not complete enough to draw them.



4 . . MULTIPLE GRAPHS, shown here for same polyester, allow reasonable visualization and permit reading data if operating temperature corresponds to the test temperature. However, interpolation can be difficult. Curves here indicate a "regular" material (without multiple peaks of loss factor β). Shape dissimilarities from curve-to-curve, or double-peaks in any one curve, usually indicate a viscoelastic material of complex behavior.

quency and amplitude of stress and/or strain (frequency, of course, being directly related to strain and stress rate), temperature, loading history (preloading), and the general mean state of stress of the material. For viscoelastic materials it turns out that all of these tend to be important under certain conditions. For example, the state of compression of rubber in "rubber-in-shear" vibration-mounts strongly influences the mounts' behavior. Also, for most materials, one may expect increases in stiffness and in loss factor when amplitudes are large enough—an amplitude dependence.

Fortunately, however, in many practical applications the stress states in viscoelastic materials are essentially one-dimensional, and preloading and amplitude effects can be neglected. Many viscoelastic materials, in fact, exhibit no amplitude effects for strains as large as unity. Frequency and temperature then are the most significant parameters, and our discussion will be limited to these two effects.

Since most of the known information about the dynamic properties of materials deals essentially with amorphous plastics, the following discussion

text continued, page 48

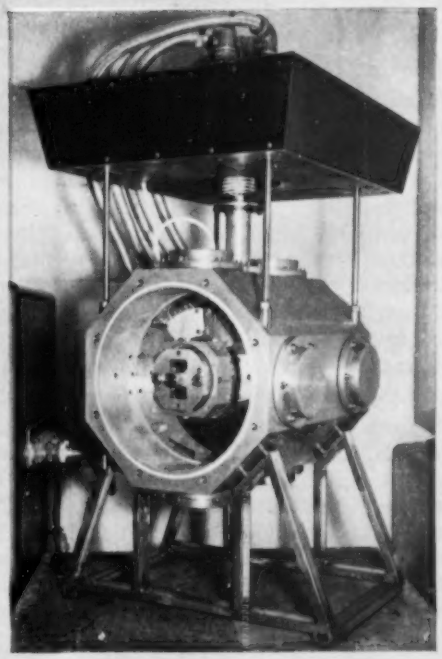
How dynamic mechanical properties are determined

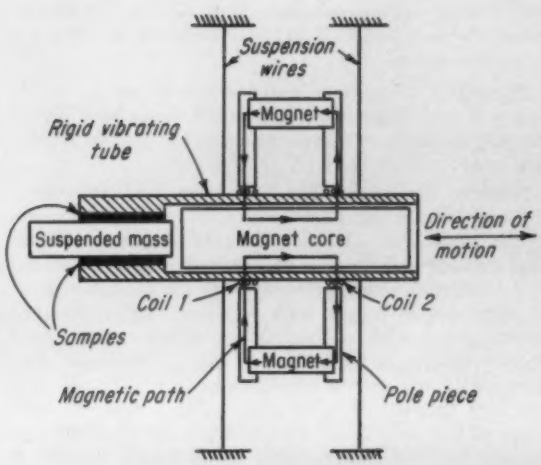
■ In all methods capable of experimentally determining dynamic mechanical properties over a continuous band of frequencies, a forced vibration is applied to a sample of the material, appropriately supported. The relation between dynamic stress and dynamic strain is then measured. The test apparatus can be designed to load the sample dynamically in tension, compression, shear, or a combination of these. Stress and strain may be the observed variables; however, any other variable will suffice if it is easily related to the modulus of the material (or its "compliance," the reciprocal of modulus), such as deflection of a beam.

Ideally, a test device should permit analysis over a wide range of sample loading rates (frequencies). This suggests the loudspeaker principle, a system that permits precise design with uniform and predictable frequency response. The Fitzgerald apparatus, made by the Chesapeake Instrument Corp, is one of the most highly developed of such devices and can be used for dynamic analysis of damping materials over a frequency range of 25 to 5,000 cps. How this apparatus works can be seen from an examination of the transducer, pictured and sketched on this page.

Two coils, placed in separate, radial magnetic fields, are mechanically coupled to each other and to the sample material by being wrapped on a rigid lightweight metal tube. This tube is suspended by wires so that it can move only in an axial direction, impeded only by the sample—which is also attached to a heavy, suspended mass in such a way that motion of the tube puts the sample in shear. The coils are isolated from each other electrically and magnetically.

An alternating current I flowing through either coil interacts with the magnetic field to produce an alternating axial force F on the coil-and-tube arrangement, setting up an oscillation of the tube proportional to the complex shear compliance (reciprocal of complex shear modulus G*, Eq 5). When the coils vibrate in the magnetic field, a voltage E is set up which is proportional to tube velocity V, and this, in turn, is related to the complex shear compliance of the sample.





Measurement of E and I gives an electrical impedance (E/I) which is related to the mechanical impedance (F/V) of the system. The complex shear modulus is calculated from the mechanical impedance. For practical design work, the complex modulus G* is broken down into the real (storage) modulus G_1, and loss factor β, the tangent of the phase angle ϕ.

Modulus data presented in this article are for shear-modulus G_1, related to tensile modulus E_1 by Poisson's ratio μ as follows: $G_1 = E_1/2(1 + \mu)$. Poisson's ratio for high-damping materials is near 0.5 so the real tensile modulus is about three times the real shear modulus. Hence, to obtain values of E_1 from the data in this article, multiply the listed G_1 values by 3. In regions of high loss, the values of loss factor β in extension and shear are equal for all practical purposes.

Beyond finding the damping properties of materials, dynamic measurements of this sort have other uses, among which are: (1) predicting electrical properties from mechanical properties, (2) checking effects of radiation on viscoelastic materials, and (3) estimating the behavior of material under flow, as in the extrusion process. ■

is centered about these materials. Some of this information can be extrapolated also to other, more crystalline materials without a great deal of difficulty, particularly if the underlying molecular mechanisms are understood.

Molecular structure provides the key

A qualitative feeling for the temperature- and frequency-dependence of the dynamic mechanical properties can be obtained by considering these properties in terms of the associated molecular motions. In a linear amorphous plastic, the deformations occurring under the action of applied stress come from motion of "segments" of the long-chain molecules. These motions may consist of coiling and uncoiling of the chains or of any general change of configuration. Such changes require a finite time, and are delayed or "retarded" by intermolecular and intra-segmental forces.

Frequency effect. If a stress is applied at low frequency, the delayed response of the segments occurs within time intervals that are small compared to the period of the stress reversals. Near-equilibrium is therefore obtained at all times. However, if the frequency of the applied stress is increased, eventually the segmental motions can no longer take place in the time within which the stress reverses. These internal motions then no longer "keep up" with the stress reversals and the material deforms less. This is why, as frequency of the applied stress increases, we find regions where the material stiffness (modulus) increases markedly. Such regions may clearly be seen in the modulus plots of Fig 3 and 4 (page 46), for a polyester resin.

Energy losses occur in a viscoelastic material because of the displacement of molecular segments against opposing molecular forces that results when the strain (displacement) is not in phase with stress. For a given stress amplitude, the energy loss per cycle is known to be proportional to the strain amplitude and to the sine of the phase angle between stress and strain. Hence at low frequencies, where the phase angle is small, the energy loss is also small. Similarly, the energy loss is small at high frequencies where the strain amplitude itself is small (because it cannot keep up with stress reversals). The highest energy dissipation thus occurs at some intermediate frequency range, where both the phase angle and the strain amplitudes assume relatively large values. This fact is also brought out by the subsequent description of measured data.

Temperature effect. We have not discussed temperature yet; constant temperature was tacitly im-

WORKING EXAMPLES

■ The damping-materials data in this article can be used to answer two kinds of materials-selection questions: (1) What material will do a given job best? (2) What are the applications for a given material? The following examples indicate such choices made purely on the basis of dynamic properties. Other pertinent information on such factors as cost, availability, ease of installation, flammability, toxicity, etc., must be obtained from the materials suppliers.

EXAMPLE 1: Select a material to be used as the viscoelastic interlayer in an instrument housing of damped sandwich construction. The instrument is to be used in boiler rooms where its temperature will be 40 to 50 C (105 to 120 F) and where it will be subjected to forcing frequencies of 600 to 1000 cps.

Solution: Examination of all the contour plots for the temperature range and frequency range specified gives the following average values of loss factor β for suitable materials (use a paper templet with a rectangular hole sized to the temperature-frequency area specified):

No.	Material	Average Loss Factor β
8	Plasticized PVC	1.2
1	Plasticized PVA	0.8
3	Polyisobutylene	0.8
14	Filled rubber	0.38
16	Aquaplas	0.35
12	Nitrile rubber	0.3
10	Polytetrafluoroethylene	0.2

Thus, from a purely damping standpoint, plasticized PVC is the best choice, with plasticized PVA and polyisobutylene as second choice. Table II lists the numbers of bibliographic references to these materials in "For More Information", p 56, where further details on source and composition will be found. Table II also lists an average modulus value which may be used to establish the required thicknesses (see "Damping Tapes for Vibration Control," *PE*—Jan 25 '60, p 57).

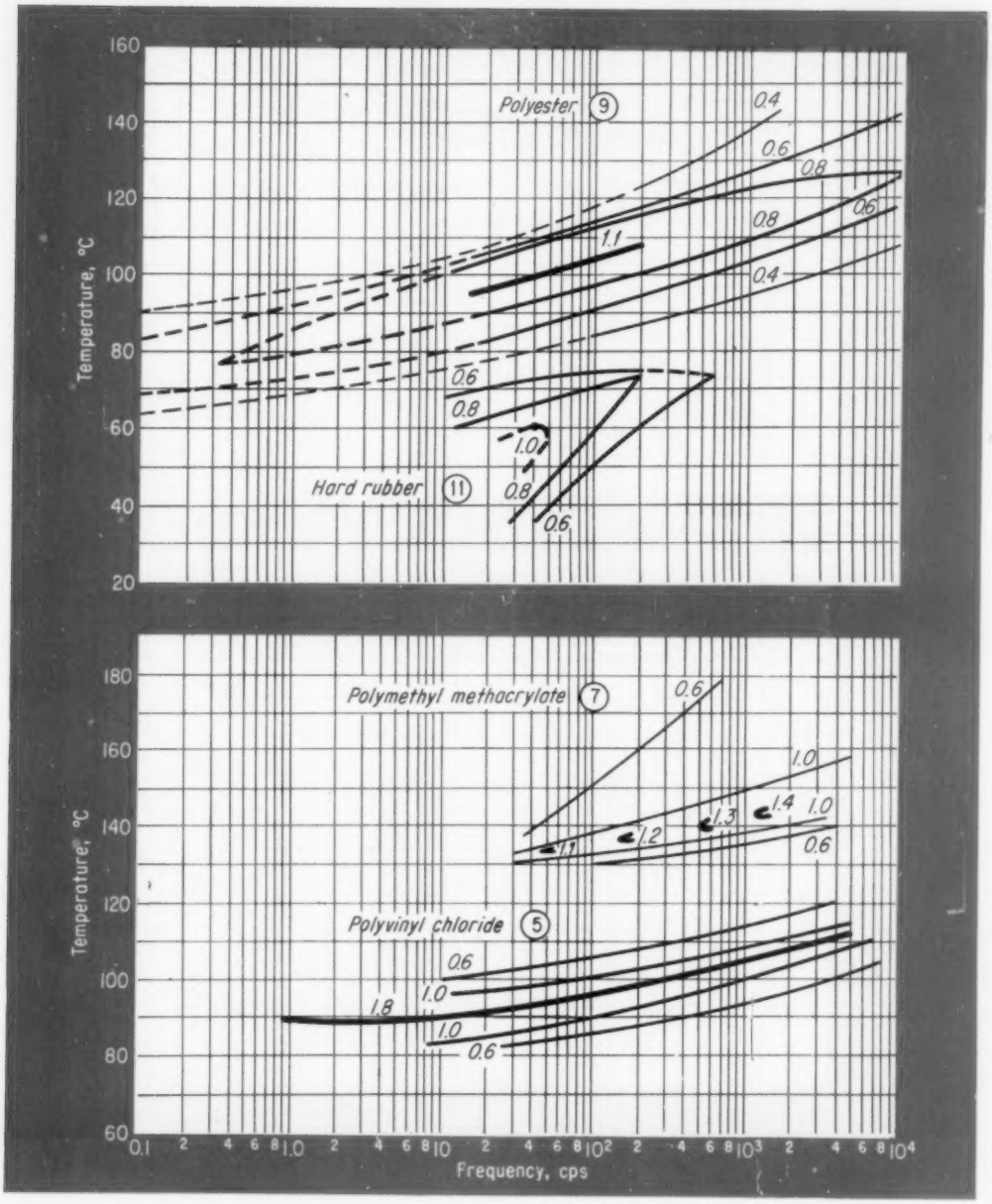
To widen the choice of materials, Table III could be used in this example, in addition to the contour plots, if the specified frequency range was lower; Table IV would apply if the operating-temperature range was closer to room temperature. Note that by starting with Table II, rather than the contour plots, only plasticized PVC and Aquaplas would have appeared as obvious choices.

EXAMPLE 2: Given polyester resin as a base for a wide variety of glass fiber-reinforced structural shapes, what do the damping properties of this plastic suggest as possible application areas?

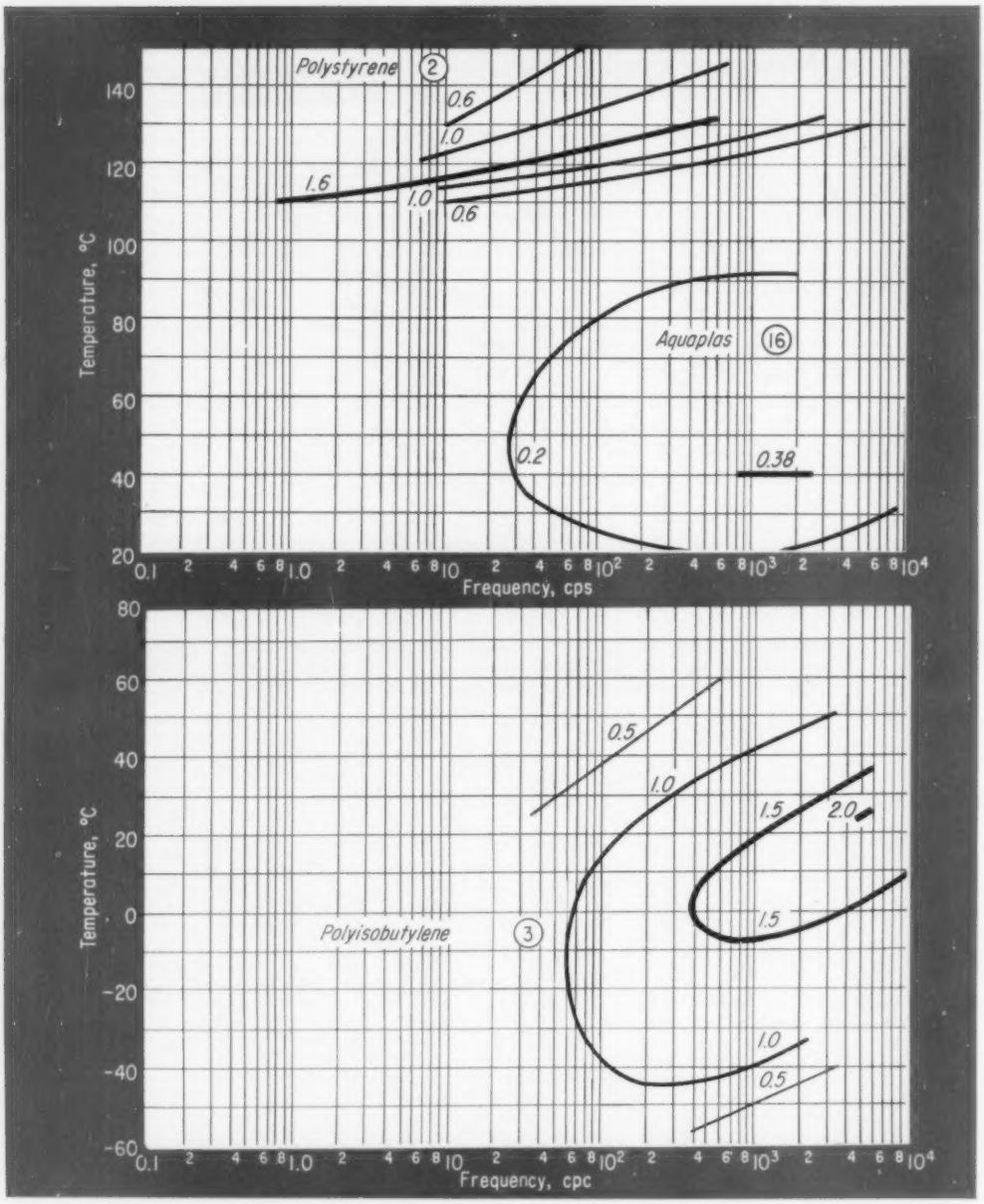
Solution: In contour plot No. 9, the loss-factor data is regular and can be extrapolated with some confidence as shown by the dashed lines. This plot shows the material can provide large amounts of damping at frequencies from 1 to 10,000 cps in the temperature range between 80 and 130 C. This suggests damping uses in or near such wide-band, high-temperature sources of vibration as internal combustion engines, space re-entry vehicles, or hot-air heating units. Concurrent structural use of the material would depend on its modulus at operating temperature. 3-D plot in Fig 3 shows modulus drops off prohibitively above about 80 C, except at very high frequencies. Glass reinforcement retards fall-off, however. ■

CONTOUR PLOTS FOR HIGH-DAMPING MATERIALS

(Heavy contour lines represent high damping values; light lines represent lower values. Contour numbers give value of loss factor.)



plied. However, because increased temperature increases mobility of molecules, its effects can be readily assessed. At higher temperatures the molecular chain motions, being less restricted, can keep up better with the applied reversed stresses. Stiffening of the material and maximum energy losses then occur at higher frequencies. The dependence of the dynamic mechanical properties on both frequency and temperature may readily be visualized by means of Fig. 3. These isometric graphs also give some idea of the "temperature-frequency equivalence" often mentioned in technical literature. This equivalence points out that a given increase in frequency at constant temperature produces the same change in the dynamic elastic properties of a given material as does a certain decrease in temperature at constant frequency. For amorphous plastics a good approximation is a decrease of 5 to 7 deg C



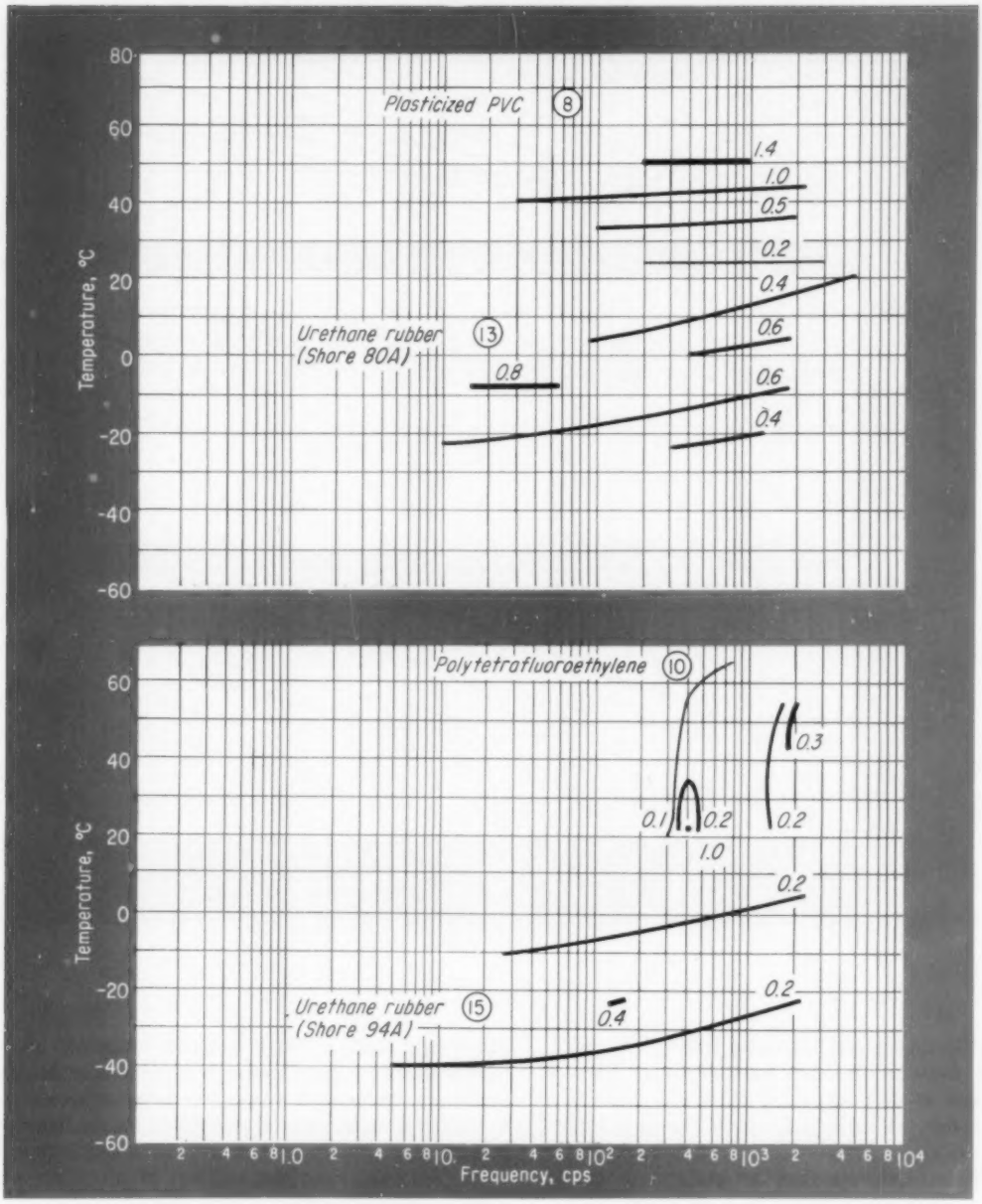
has the same effect as an increase in frequency by 10 times. Greater shifts occur at higher frequencies.

Effect of constituents. Molecular considerations permit some prediction here too. Constituent changes may take the form of changed plasticizer and/or filler content, copolymerization, or polyblending. The addition of plasticizer (essentially diluting the polymer with an organic liquid) increases the chain mobility and softness of a material, so that increased plasticizer content has somewhat the same lowering effect on stiffness as does increased temperature at all frequencies.

Looking at the 3-dimensional plots of Fig 3, this means that the modulus surface and loss-factor surface are, in effect, shifted toward lower temperatures. Stiffness at a given temperature and frequency thus decreases somewhat. Loss factor drops, too, probably because adding plasticizer reduces the amount of viscoelastic material in the specimen.

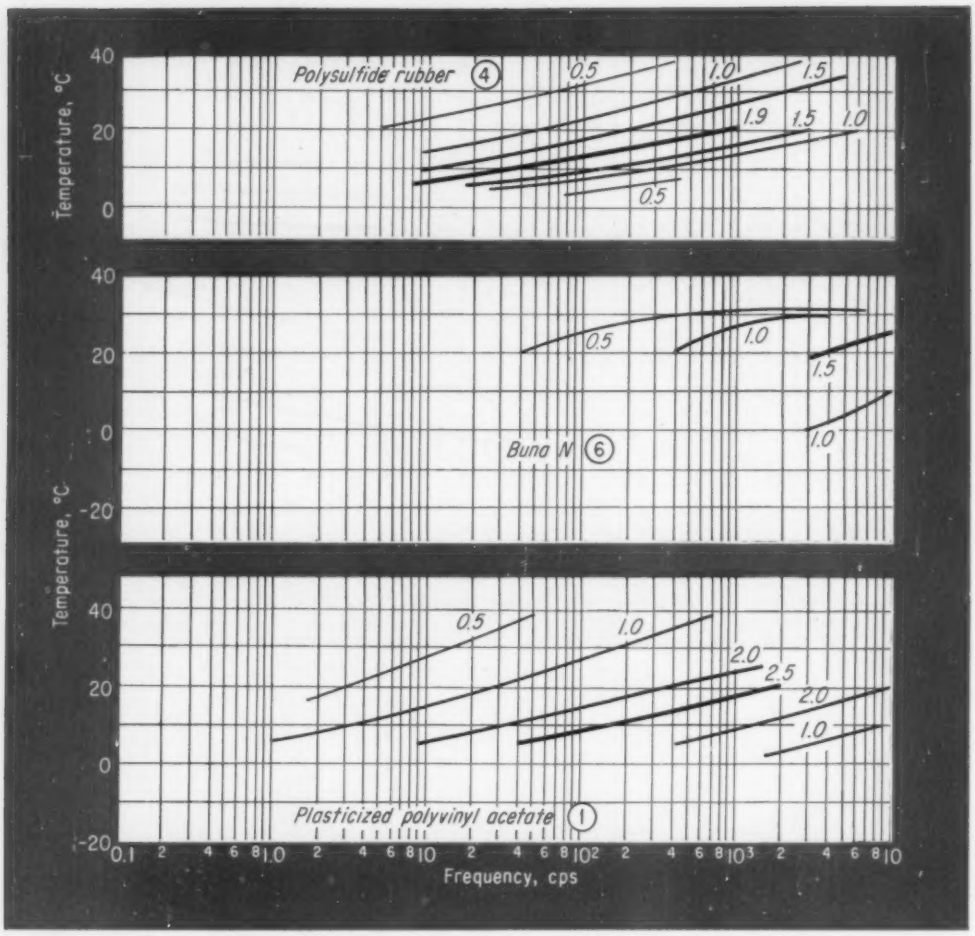
A filler (a polymerically inert material), on the

(Heavy contour lines represent high damping values, light lines represent lower values. Contour numbers give value of loss factor.)



other hand, may be expected to have little effect on the temperature- and frequency-changes in properties of the viscoelastic material, since a filler does not act chemically on the polymer chains and so does not affect their mobility markedly. There is consequently little or no translation of the modulus surface or loss-factor surface. A filler serves mainly to replace some viscoelastic material by non-viscoelastic material; increased filler content thus decreases the total-loss factor somewhat and changes the stiffness at all frequencies by some amount which depends on stiffness and proportion of the filler material. Copolymerization (the linking of two polymeric materials) and polyblending (the mechanical mixing of two polymers) result in materials with properties intermediate to those of the two basic polymers, though the effect is more pronounced for copolymers.

Effects of other parameters. An increase in crystallinity (a decrease in randomness of the molec-



ular chain arrangements) generally strengthens the inter-chain forces. Cross-linking (joining of amorphous chains at intervals along their lengths) has the same result. So it should not be too surprising that increases in either one or both of these parameters result in materials that are stiffer and that have their loss-factor maxima and rapid modulus changes at lower frequencies or higher temperatures.

The degree of polymerization of a material and the distribution of its molecular weight may also influence its dynamic mechanical properties. The effects of these two variables are not quite so easily explained and are only partly understood. However, it is known that the effects are relatively small for high polymers.

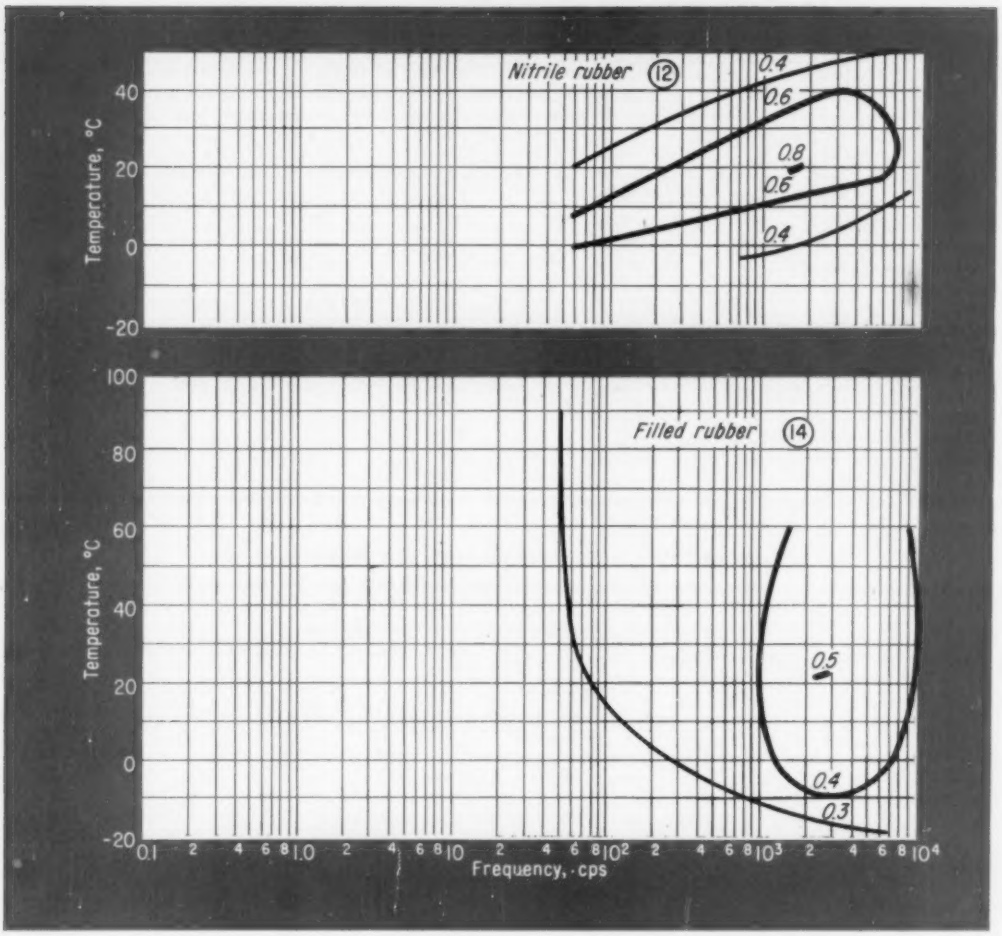
CAN VISCOELASTICS BE TAILORED?

As suggested by the previous section on behavior, viscoelastic materials may virtually be made to order by proper selection and compounding of polymers, plasticizers, and fillers. Polymer designers have studied some of these things in considerable detail, and often can predict quantitatively what a certain modification of a material will do to its mechanical properties.

For example, since the addition of plasticizer to a given polymer serves to shift the G_1 and β surfaces, adjustment of plasticizer content provides a convenient way to adjust the region of maximum damping to the desired temperature and frequency ranges. This translation, however, does not occur entirely without distortion.

Or take fillers. Adding a filler shifts the G_1 and β surfaces of Fig 3 only very little with respect to the frequency and temperature axes, but it does lower the loss factor and change modulus. Details of these changes depend on the moduli and on the amount of filler added: a stiff filler may stiffen the material, and a soft filler may soften it; if the filler itself is viscoelastic, its losses may make themselves appar-

(Heavy contour lines represent high damping values, light lines represent lower values. Contour numbers give value of loss factor.)



ent in addition to those of the basic material. Thus, the addition of filler provides a relatively convenient way to adjust magnitudes of the stiffness of the material without affecting temperature and frequency dependences much.

WHAT ARE THEIR PROPERTIES?

Presentation of data on the dynamic mechanical properties of viscoelastic materials is complicated by the fact that the properties depend on frequency and temperature. Isometric graphs like those of Fig 3 are extremely useful for purposes of visualization, but usually cannot be made to yield good quantitative information. Multiple graphs like those of Fig 4, on the other hand, are sufficient for most quantitative purposes, and are also reasonably adequate for visualization. The curves are of constant temperature; Fig 4 may, in fact, be considered a projection of a number of constant-temperature profiles from Fig 3 onto a single plane.

But there is a better scheme. For damping or energy-dissipation purposes, we must select or design a material where the region of large β corresponds to the region of intended use. Thus, some description of the frequency-and-temperature location of the region of high loss factor may suffice to characterize a given material.

Based on this idea, a relatively convenient method of presenting viscoelastic materials data consists of plotting, for every material considered, contours of constant loss factor β in the frequency-temperature plane, and of listing an average value for the shear modulus G_1 (or tensile modulus E_1) that applies in the region of highest loss factor. A single value of E_1 or G_1 can characterize a material fairly well because the elastic moduli E_1 or G_1 change relatively little along the contour of highest damping.

Tables II, III, and IV, along with the contour plots, represent a damping-materials catalog based on this data-presentation scheme. The catalog, a

II—DYNAMIC-PROPERTY DATA FOR WIDE RANGE OF TEMPERATURE AND FREQUENCY

(summarizes most useful data from the contour plots)

Material	Max loss factor, βmax	Position of βmax freq., cps	temp, °C	Shear† Modulus G_1 at βmax, psi	Reference Nos.
1. Plasticized polyvinyl acetate	2.6	50	5	2,180	15
2. Polystyrene	>2.0	>2000	~140	14,500	1, 14, 3
3. Polyisobutylene	>2.0	>6000	25	290	11, 18, 4
4. Polysulfide rubber (Thiokol RD)	1.9	7	5	10,100	16
5. Polyvinyl chloride	1.8	20	92	3,330	1, 14, 3
6. Buna N (Type B-1), vulcanized	1.5	4000	20	1,450	9
7. Polymethyl methacrylate	1.5	1200	142	14,500	1, 3
8. Plasticized PVC (Koroseal)	1.45	660	50	3,470	5
9. Polyester	1.1	200	108	10,100	3, 11
10. Polytetrafluoroethylene (Teflon-TFE)	1.0	400	23	5,800	5
11. Hard rubber	1.0	40	60	10,100	1
12. Nitrile rubber	0.8	1800	20	15,900	11
13. Urethane rubber (Shore 80 A)	0.8	30	−8	2,320	1
14. Filled rubber	0.5	2500	22	33,300	1
15. Urethane rubber (Shore 94 A)	0.4	140	−23	43,500	1
16. Aquaplas (water soluble)	0.38	1000	40	24,200	1

† To get tensile modulus E_1, multiply G_1 figures by 3.

III—DYNAMIC-PROPERTY DATA AVAILABLE AT LOW FREQUENCIES ONLY

(contour plots not yet available for these materials)

Material	Max loss factor, βmax	Temp range, °C (for $\beta \geq 0.75\ \beta$max)	Test Freq., cps	Shear† Modulus G_1 at βmax, psi	Reference Nos.
Polyvinylcarbazol	>1.6	200 to 220	10.0	1,200	14
Polyvinyl-N-butyl ether	>1.6	−40 to −20	0.8	1,500	14
Polyvinyl-isobutyl ether	>1.6	−15 to 10	1.2	1,500	14
Polyvinyl-tert-butyl ether	>1.6	70 to 90	1.7	1,500	14
Butyl rubber (unvulcanized)	1.2	−20 to 20	1.0	15,000	14
Neoprene GN-50 (vulcanized)	0.5	−20 to 5	~150.0	5,800	9
Natural rubber (high mol. wt)	~0.5	−70 to −50	<10.0	1,500	19
GR-S rubber	~0.5	−60 to −40	<10.0	7,200	19
Polytrifluorochloroethylene (eg. Fluorothene)	0.42	90 to 120	3.3	11,600	14
Polyvinylfluoride	0.36	20 to 60	1.7	5,800	14
Polyethylene	0.23	30 to 80	12.0	2,900	14
Buna N (B-5), carbon-filled, vulcanized	0.15	0 to 10	50.0	29,000	9

† To get tensile modulus E_1, multiply G_1 figures by 3.

compilation of information amassed from available literature, is arranged in three sections:

1. Where enough data are available to describe behavior of the material over reasonably wide ranges of frequency and temperature, these data are presented in terms of constant β contours in the frequency-temperature plane, with modulus G_1 data listed separately in Table II. Only materials with relatively high damping are considered.

2. For materials whose data are available only for low frequencies, the maximum low-frequency loss factor and its corresponding modulus and frequency are tabulated in Table III. For design purposes, a temperature range is given within which the loss factor is at least three-quarters of its maximum value.

3. Where only room-temperature data are available these are extracted in tabular form in Table IV, with loss-factor data over a wide frequency range given, in addition to maximum loss factor and its corresponding modulus G_1.

SOME LIMITATIONS

Several important qualifications and limitations should govern use of the information (see "Working Examples," p 48) given in this materials catalog:

First, many of the constant β contours are incomplete because of lack of data. However, existing contours can be extrapolated with some confidence if the sort of trends that occur in Fig 3 are kept in mind. The contour plot for a polyester (material

IV—DYNAMIC-PROPERTY DATA AVAILABLE AT ROOM TEMPERATURE ONLY

(contour plots not yet available for these materials)

Material	Max loss factor, βmax	Frequency for βmax, cps	Loss factor at five frequencies (cps): 1	10	100	1,000	10,000	Test Temp, °C	Shear† Modulus G_1 at βmax, psi	Reference Nos.
Polysulfide rubber (Thiokol H-5)	5.00	1,000	0.17	0.50	1.20	5.00		25 ± 50	1,500	12
Butyl rubber (Enjay 9–262–4)	4.02	3,100			0.40	0.92	>2.0	21	1,500	2
Urethane rubber (Disogrin IDSA 9250)	2.59	3,000			0.10	0.13	~0.50	25	2,900	2
Butyl rubber (Enjay 9–262–1)	2.56	3,000			0.55	0.84	>1.80	21	2,900	2
(Enjay 9–262–3)	2.20	3,000			0.45	0.68	>1.40	24	2,900	2
Polyvinyl butyral	2.0	2		0.14	0.06	0.06		30 ± 70	29,000	13
3M tape adhesive, No. 466	1.82	1,000		~1.00	1.17	1.82	~0.80	25	360	7
Butyl gum (Type U-50), vulcanized	1.80	10,000				1.20	1.80	20	1,000	9
Buna N (Type B-5), carbon-filled, vulcanized	1.60	10,000		0.40	0.75	1.20	1.60	20	1,500 to 4,400	9
GR-S rubber	1.60	10,000		0.20	0.50	1.00	1.60	20	1,500	17,6
Urethane rubber (82% Pb powder filler)	1.40	3,000			0.40	0.49		25	2,500	2
Fluoro rubber (3M No. IF4)	1.30	4,000		~0.30	0.46	0.79		45 ± 55	17	7
Neoprene GRT	1.18	1,775			0.60	1.01		20	220	8
Polyvinyl chloride acetate	1.14	100			1.14	0.73	0.90	40 ± 20	580	7
Neoprene (Type GN-50), vulcanized	1.10	10,000				0.70	1.10	20	290	9
Buna N (Type B-O), unvulcanized	1.00	1,000		0.50	0.65	1.00		15	1,200	9
Hycar 1014	0.76	1,850			0.40	0.63		20	200	8
3M damping tape adhesive, No. 435	0.73	4,000		~0.50	0.58	0.67	~0.70	10 ± 50	37	7
Neoprene (Type CG-1), vulcanized	0.60	10,000				0.02	0.60	20	4,350	9
Fluro silicone rubber (Silastic LS53)	0.56	4,000		~0.10	0.16	0.46		30 ± 70	87	7
Polysulfide rubber (Thiokol ST)	0.53	1,300			0.40	0.51		20	160	8
Urethane rubber (Disogrin IDSA 7560)	0.51	4,250			0.10	0.22		25	1,500	2
GR-S rubber (23.5% styrene)	0.47	1,700			~0.30	0.39		20	200	8
(3.0% styrene)	0.38	1,400			~0.25	0.37		20	13	8
GR-S (Type S-50) carbon-filled, vulcanized	0.35	10,000				0.20	0.35	20	435	9
Silicone gum (Linde No. Y-1032)	0.33	400		~0.15	0.20	0.40		60 ± 40	2.5	7
Natural gum rubber (Type N-1)	0.30	1,000	0.04	0.08	0.14	0.30		20	150	9
GR-S rubber (Krylene)	0.30	10,000	0.11	0.12	0.13	0.15	0.3	20	100	15
Hevea rubber (filled)	0.25	10,000	0.11	0.11	0.11	0.14	0.25	20	870	15
(vulcanized)	0.20	10,000	0.03	0.03	0.03	0.05	0.20	20	870	16
Natural rubber (Tire tread stock)	0.20	500	0.16	0.18	0.20			25 ± 50	150	12

† To get tensile modulus E_1, multiply G_1 figures by 3.

No. 9 in Table II) has been extended this way.

Second, Fig 3 is an over-simplification; there are probably more wiggles and secondary maxima in the surfaces representing these functions for most materials. This is particularly true of crystalline or partially crystalline materials, where several secondary maxima and "resonance-dispersion" regions have been observed in areas removed from the primary damping maximum.

Third, keep in mind that relatively slight changes in material composition can have considerable effects on the dynamic elastic properties and on their temperature and frequency dependences.

Fourth, these data concentrate on the high-damping regions of the loss factor-temperature-frequency relationship. Care should therefore be exercised in selecting materials from this catalog for low-energy dissipation or nondissipation purposes. Such materials should be selected so that operating conditions correspond to one of the nearly flat plateau regions of modulus G_1. Because these regions are removed from maximum loss factor, they are on the fringes of the contour plots given here.

Fifth, space limitations required omitting detailed compositions and treatments of materials. However, literature references given in each tabulation are listed in the bibliography, so that additional information may be obtained from the original source for materials of particular interest.

continued, next page

FOR MORE INFORMATION

■ Data for Tables II, III, and IV and for the contour plots were drawn from the sources listed below. Reference numbers correspond to those given in the tables. With each reference is a brief summary of its contents. The 19 references listed here have been selected from a voluminous bibliography in this field and cover, in addition to the materials property data: methods of test, concepts of viscoelastic damping methods of calculation, and applications to specific problems like vibration isolators.

1. Becker, G. W. and H. Oberst, "Uber das dynamisch-elastische Verhalten linearer, vernetzter und gefüllter Kunststoffe", *Kolloid Zeitschrift*, Vol. 148, Nos. 1-2, pp 6-16 (1956)—Arranges plastic into linear, cross linked and filled classes. Data on a number of materials.

2. Cook, E. J., J. A. Lee, E. R. Fitzgerald, and J. W. Fitzgerald, "Dynamic Mechanical Properties of Materials for Noise and Vibration Control," Chesapeake Instrument Co., Shadyside, Md., Report No. 101 (1 Jan 1960), Contract No. NOnr-2678 (00). Summary of concepts of complex dynamic moduli and compliances; compilation of some material data. A continuation of reference 5.

3. Ferry, J. D., W. C. Child, R. Zand, D. M. Stern, M. L. Williams, and R. F. Landel, "Dynamic Mechanical Properties of Polyethyl Methacrylate," *J. Coll. Sci.*, Vol. 12, No. 1, pp 53-67 (Feb. 1957)—Data obtained by Fitzgerald Apparatus, 24-2400 cps, 75°-155°C for two molecular weights.

4. Ferry, J. D., E. R. Fitzgerald, L. D. Grandine, Jr., and M. L. Williams, "Temperature Dependence of Dynamic Properties of Elastomers; Relaxation Distributions," *Ind. Eng. Chem.*, Vol. 44, pp 703-706 (1952)—Discusses temperature-frequency equivalence, introduces method of reduced variables.

5. Fitzgerald, E. R., J. W. Fitzgerald, and A. E. Woodward, "Dynamic Mechanical Properties of Plastic Materials," Chesapeake Instrument Co., Shadyside, Md., Final Report (1 June 1959) Contract No. NObs-72100. Summary of viscolastic wave propagation, concepts of complex moduli and compliances; data on several materials in wide temperature and frequency ranges.

6. Ivey, D. G., B. A. Mrowca, and E. Guth, "Propagation of Ultrasonic Bulk Waves in High Polymers," *J. Appl. Phys.*, Vol 20, p 486 (1949)—Loss-factor data on vulcanized Hevea, GRS and butyl rubbers for −30 to 60°C, at 40 kc-10 mc.

7. Lazan, B. J. and L. E. Goodman, "Material and Interface Damping," Chapter 36 of Handbook of Shock and Vibration Control, C. Harris and C. Crede, Ed., McGraw-Hill Book Co., Inc. (to be published August 1961)—Authoritative summary on various phases of damping, including viscoelastic.

8. Morris, R. E., R. R. James, and C. W. Guyton, "A New Method for Determining the Dynamic Mechanical Properties of Rubber," Rubber Age, Vol. 78, pp. 725-730 (Feb 1956)—Double Transducer apparatus for impedance measurements. Data on nitrile and natural rubber 0-1400 cps.

9. Nolle, A. W., "Dynamic Mechanical Properties of Rubberlike Materials," *J. Polymer. Sci.*, Vol. 5, No. 1, pp 1-54 (1950)—List of measurement methods; data on natural, buna N, butyl, neoprene, GRS rubbers.

10. Nolle, A. W., "Methods for Measuring Dynamic Mechanical Properties of Rubberlike Materials," *J. Appl. Phys.*, Vol. 19, No. 8 pp 753-774, (Aug 1948)—Discusses 5 test methods for 10^{-1} to 10^{5} cps. Gives equations applicable to each. Shows $G = E/3$ in dispersion region. Defines dynamic elastic properties. Extensive bibliography.

11. Oberst, H., "Werkstoffe mit extrem hoher innerer Dämpfung," *Acustica*, Vol. 6, Beiheft 1, pp 144-153 (1956)—Excellent introduction to the viscoelastic damping field, very comprehensive bibliography. Shows how to tailor high polymers for damping use.

12. Philipoff, W., "Mechanical Investigations of Elastomers in a Wide Range of Frequencies," *J. Appl. Phys.*, Vol. 24, No. 6 pp 685-689 (June 1953)—Use of a shear vibrometer 10^{-6} to 1 cps; data on a few types of rubber.

13. Rorden, H. C., and A. Grieco, "Measurement of Dynamic Internal Dissipation and Elasticity of Soft Plastics," *J. Appl. Phys.*, Vol. 22, pp 842-845 (June 1951)—Pendulum and tuning fork shear impedance measurements. Room temperature data on Pyrelin, Koroseal, Keldur, Thiokol, gum rubber, Polyvinyl Butyrol.

14. Schmieder, K. and K. Wolf, "Mechanische Relaxationserscheinungen in Hochpolymeren," *Kolloid Z.*, Vol. 134, pp 149-180 (1953)—Low frequency data on several high polymers for −190° to +100°C. Extensive bibliography.

15. Snowdon, J. C., "Reduction of the Response to Vibration of Structures Possessing Finite Mechanical Impedance, Part I," Willow Run Laboratories, U of Michigan, Ann Arbor, Technical Rept. No. 2892-4-T, (November 1959)—Same as reference 16; review of dynamic mechanical properties of rubber-like materials.

16. Snowdon, J. C., "Reduction of the Response to Vibration of Structures Possessing Finite Mechanical Impedance, Part II," Willow Run Laboratories, U of Michigan, Ann Arbor, Technical Rept. No. 2892-6-T, (January 1960)—Use of viscoelastic rubber in design of better vibration mountings.

17. Snowdown, J. C., "Choice of Resilient Materials for Anti-Vibration Mountings," *Brit. J. Appl. Phys.*, Vol. 9, No. 12, pp 461-9, (December 1958)—Criteria for good vibration mount material; desired damping vs. frequency characteristic.

18. Williams, M. L., R. F. Landel, and J. D. Ferry, "The Temperature Dependence of Relaxation Mechanisms in Amorphous Polymers and other Glass-forming Liquids," *J. Amer. Chem. Soc.*, Vol. 77, p 3701 (1955)—Method of reduced variables.

19. Zapas, L. J., S. L. Shuffler, and T. W. DeWitt, "A Comparison of the Dynamic Properties of Natural Rubber and GR-S," *J. Polymer. Sci.*, Vol. 18, pp 245-256 (1955)—Data at 10^{-6} to 1 cps, −40 to +65°C. ■

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EDITOR'S NOTE: Other articles that also cover vibration-control techniques include the following:

Damping Tapes for Vibration Control, Jan 25 '60, p 57—A cheap, reliable, and lightweight way to dissipate excess vibratory energy — keeping resonance stresses low. Basic equations and sample problem show how.

Dry-friction Damped Isolators, Aug 3 '59, p 48—Curves compare this type with better-known viscous isolators; new equations predict vibration-transmissibility characteristics of dry-friction type.

Rubber Vibration Isolators, July '57, p 140—New method of analysis predicts performance by accounting for creep of visco-elastic materials.

Manganese-Copper High-damping Alloys, May '56, p 135—Presents mechanical properties, fabrication characteristics, and potential applications of alloys having the unusual combination of high tensile strength and high damping capacity.

Damping Capacity of Materials, Nov '54, p 164 — Inherent damping capacity of structural materials is an important means of limiting resonant stresses and amplitudes of vibration. Article compares basic materials, shows how to build damping into uniformly and nonuniformly stressed members. —Ford Park

One-shot photocopier rushes duplicates

The first completely automatic copying machine turns self on, makes exposure, peels away negative, trims positive, delivers developed print and turns self off— all in just 23 seconds. Reserve tank refills developer supply.

The wide market for office convenience-copying equipment and supplies has developed in only 10 years to annual sales of more than $250 million in 1959—and most observers estimate its full potential is in the billions. Ozalid Div, General Aniline and Film Corp, Johnson City, NY, long a producer of equipment and supplies for the diazo copying processes familiar in engineering departments, noted two years ago that its products were tending closer and closer to the photographic in terms of both the process itself and reproduction quality.

Ozalid decided to develop a photocopying machine for this high-potential market, but realized it had to overcome its late start by offering equipment that was radically different. The goal selected was completely automatic operation, a machine that would eliminate the secondary paper-handling usually required to produce a finished copy. Up to now, the process has required feeding the machine with a sandwich made of the original and a sheet of sensitized paper. Some machines then deliver a copy and the original, but many others produce a negative which must be sandwiched with a positive sheet, developed and peeled apart. Alignment of the various sheets, developing, and time between developing and peeling all affect quality of the finished copy and a large wastepaper basket is usually an essential accessory. Ozalid's copy machine produces automatically: the original is slipped into the unit and the finished copy is delivered ready for use.

The new machine has been designed for an application of interest to engineering and other offices already equipped with Ozalid's standard diazo equipment: multiple copies can be made by making a translucent negative in the new machine. This negative can then be used to make copies in conventional diazo equipment, at a cost of about 1¢ a copy compared with 8¢ per sheet in office photocopy equipment and paper.

Price was important with the new Ozalid machine: despite its more expensive, all-automatic character, the price could not be more than $100 over that of the highest price semiautomatic on the market. This created several engineering design problems, in terms of cost limitations on developing the complex components required for automatic operation.

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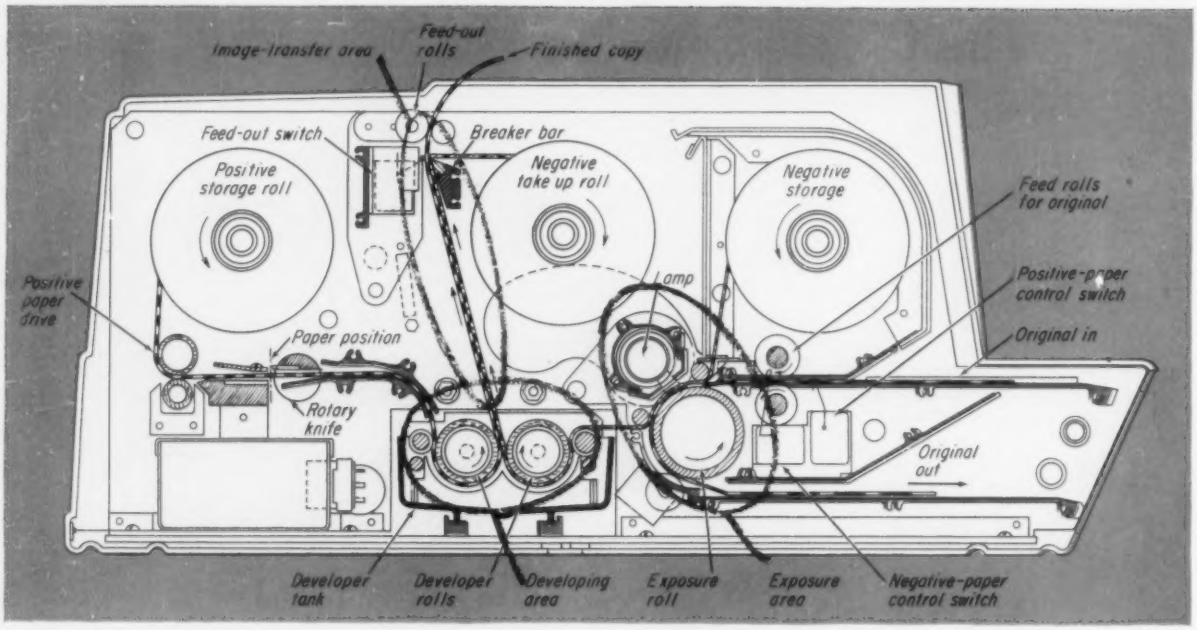


COPIER TURNS ON when original is inserted. Leading edge activates the unit by tripping control switches for both positive and negative paper. The positive-paper control switch energizes a magnetic clutch in the storage-roll drive. The feed rolls pick up the original and pass it to the exposure section. Original and negative are in contact as they pass slit in the lamp housing. Original then continues around the exposure roll and is discharged at front of the unit. When trailing edge of the original clears the positive-paper control switch, it trips the solenoid-actuated knife which rotates 45°, cutting off the positive paper and disengaging the paper-feed clutch.

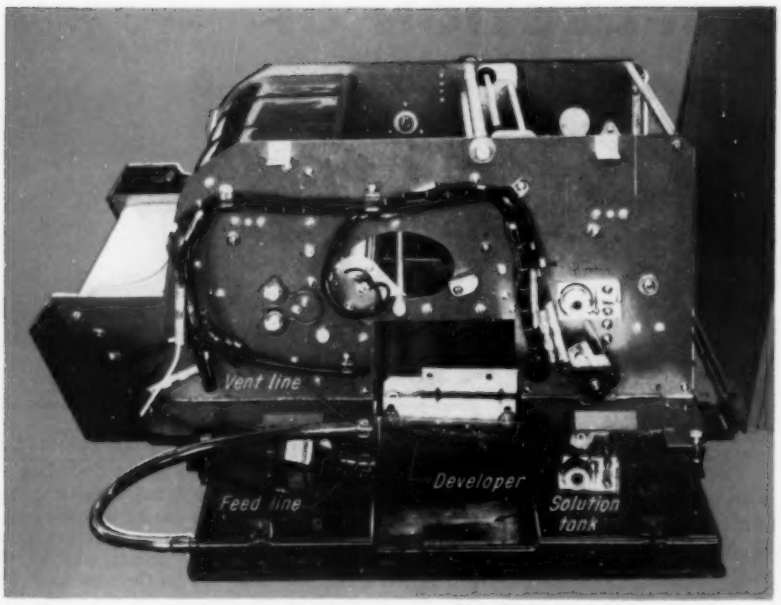
The image on the negative paper meets the leading edge of the positive paper at the contact point of the developer rolls. Negative and positive are squeezed together and held in contact as they travel through the image-transfer area. When the leading edge of the positive paper reaches the breaker bar, it continues straight up through the feed-out rolls. The breaker bar peels the negative paper away from the positive as it is rewound on the negative takeup roll. When the trailing edge of the copy clears the feed-out switch, the machine shuts off.

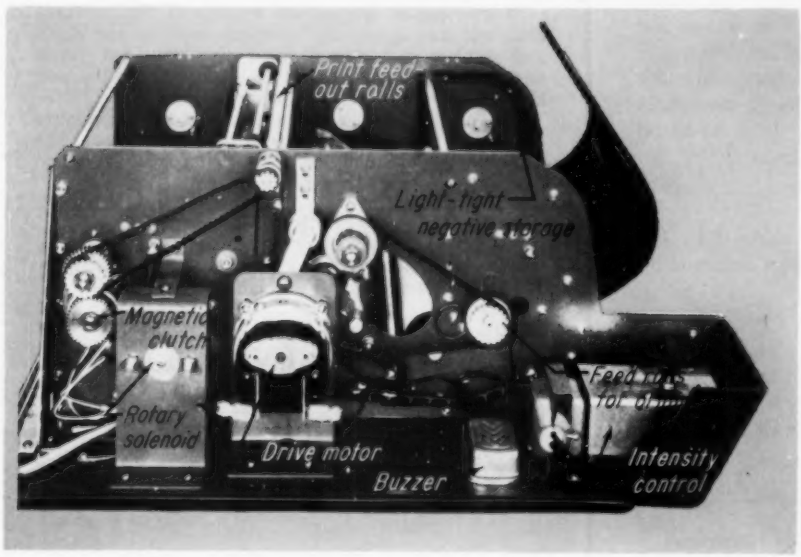
Slit in the 14-w fluorescent-lamp enclosure is wider at ends to balance exposure intensity. Output at ends is weaker so slit is wider to compensate.

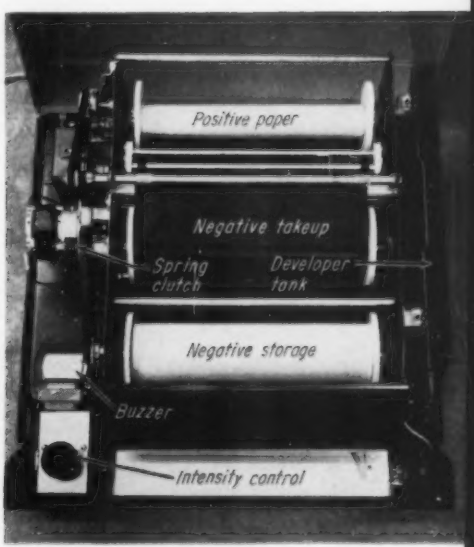
Roll of silver halide negative paper is enclosed in light-tight box. Slit in this roll 36 in. from the end trips switch to sound an audible alarm when paper is exhausted.

The role of the industrial designer was larger in the development of this machine than in most Ozalid products, which usually go into a behind-the-scenes print room or other such production area. New convenience copier had to be suitable in an office containing other equipment, of modern styling. Size was also important —it would have to compete for available desk or table space.

The engineers first showed the machine-in-development to Ozalid's staff industrial designer when they had a rough working prototype completed. All working components had to be completely accessible and such parts as the developer tray had to be removable for cleaning. Electrical components such as the control box, motors and switching gear had to be easily replaceable. This meant that housing the machine was mainly a question of where to break it between top and bottom covers, where to hinge it for accessibility. The bezel was made a separate entity because the machine was to be distributed by dealers whose own company names might need to be incorporated in the front panel. A bezel separate from the all-plastic case was selected so that the other nameplates would not require retooling the case for each supplier.







ACCESSIBILITY was a prime design consideration; it allows operator to replenish developer and paper or make repairs. One-piece plastic top is hinged at rear, flips up to expose entire mechanism. Developer tray and paper rolls slide out for cleaning. Upright air-tight tank, which hangs on the right-hand side of the unit, supplies fresh developer to replace that removed from the tray during processing. Solution flows into developer tray through the feed line whenever fluid level drops below the vent line. When the fluid covers the vent, air to the supply tank is cut off and fluid flow stops. Tank is refilled by turning it on its side and pouring fluid into developer tray.

Flexible toothed driving belts synchronize the paper drives. Two belts drive all paper-handling rolls and rollers from a single drive motor; a rotary solenoid is used for positive-paper cutoff. Spring clutch on negative-paper takeup drive keeps web tension constant.

Construction is simplified by using two side plates joined by the aluminum extrusions that guide the moving paper. All extrusions were designed to be fastened to the side plate by self-tapping screws. Paper-handling mechanisms were located between side plates but all driving mechanisms were mounted outside the plates for easy access. Large kidney-shape opening on side plates allow lamp housing to be pivoted clear for replacement of its fluorescent bulb.

how to ANALYZE DEFLECTION OF SLEEVED SHAFTS

Here is a practical method that takes composite-beam theory a step further . . . it includes the effect of interference fits.

T V DUGGAN, *design engineer, Aero Div, Rolls-Royce Ltd, Manchester, Eng*

When sleeves and stepped shafts are assembled with interference fits, calculating the deflection in the shaft can be very complicated. Such calculation is particularly important where it is necessary to consider critical speeds and natural frequencies, and as explained in the box at right, many applications require a practical method that allows for stiffening of the shaft caused by the interference fit.

To meet the need, two completely different approaches to the problem have been developed. The first is the classical method, involving precise solution of differential equations. It is based on the idea of change in shaft length. The second, developed here, offers a reasonably accurate solution with much less effort. It is based on what might be called the restraint of strain.

Restraint-of-strain principle

Three sketches show how this idea works. In Fig 2(A) a unit cube with a single stress f_1 causes deformation

SYMBOLS

- E — Young's modulus of elasticity (E_1 for shaft, E_2 for sleeve)
- e — Unit strain = x/L
- f_1 — Unit stress caused by simple bending, psi
- f_2 — Interference stress, psi
- I — Moment of inertia of shaft section (subscripts identify sections) number of in.^{4}
- L — Shaft length, in.
- M — Bending moment, in.-lb
- m — Ratio E_2/E_1
- R — Sleeve radius, in.
- r — Shaft radius, in.
- T — End reaction, lb
- x — Deformation, in.
- W — Total load on shaft, lb
- α — Ratio of unit strains with and without interference stress $\left(\frac{e}{ec}\right)$
- δ — Radial interference between sleeve and shaft, in.
- λ — Poisson's ratio — 0.3 for steel shaft

COMPOSITE-BEAM THEORY WITH CRITICAL SPEEDS

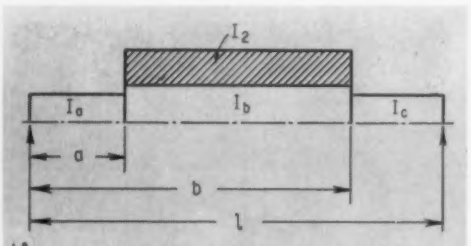
■ The deflection in stepped shafts caused by the interference fit with the sleeve is important if critical speeds are involved. The problem can be simplified by assuming the sleeve and shaft are integral and solving by analysis of composite beams. But the results may be misleading, allowing excessive deflection for the same load. This lowers the estimated natural frequency of the assembly, and may lead to machine failures.

Where critical speeds and frequencies are unimportant, one may ignore the stiffening effect of the sleeve and use it as an additional factor of safety. But this is not always feasible or economical; we then need a suitable technique for analysis of deflection.

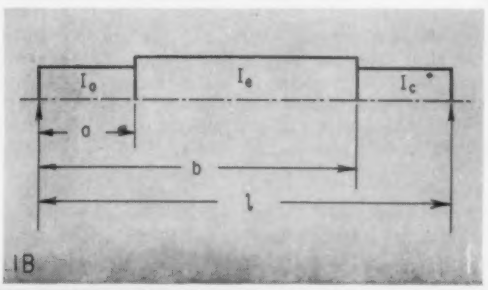
The usual practice calls on composite-beam theory to divide the sleeved shaft, Fig 1(A) into sections. The section with the sleeve is replaced by a composite section with an equivalent moment of inertia as follows:

$$I_e = I_b + mI_2$$

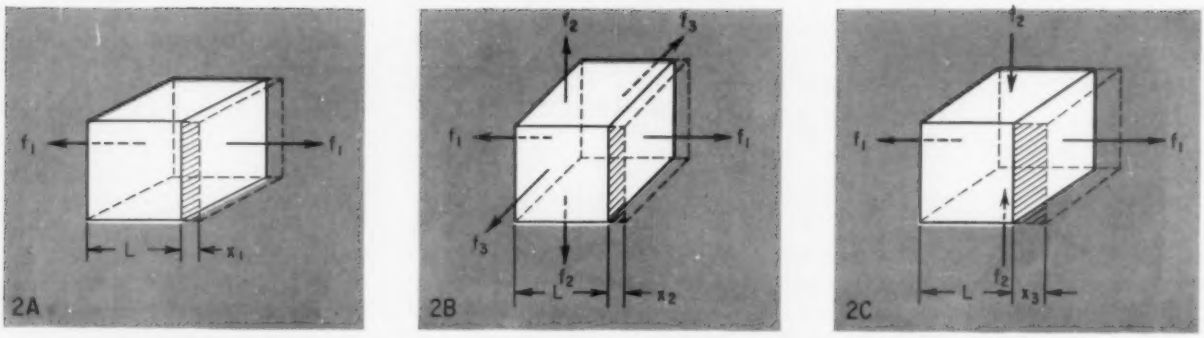
which results in an equivalent shaft Fig 1(B). But this method does not take into consideration the stiffening of the shaft caused by the interference fit. ■



1A



1B



UNIT CUBE UNDER SIMPLE STRESS (A) produces a greater strain than the complex stresses in (B). But in (C), with two-dimensional stress system, strain is relatively larger because vertical stress is compressive.

x_1 and unit strain $e_1 = x_1/L$. This gives:

$$E = f_1/e_1$$

In Fig 2(B), with a complex stress system, $e_e = x_2/L$, but x_2 is less than x_1 and therefore e_e is less than e_1, so

$$\alpha E = f_1/e_e$$

The value αE is greater than E, because e_e is less than e_1. This shows that by restraining the deformation in the direction of f_1 the value for the modulus has been increased in this direction, giving an apparent value αE.

In Fig 2(C) a two-dimensional stress system produces similar results. The only difference here is that stress f_2 is reversed in direction, giving greater deformation, x_3, in the direction of f_1 than in Fig 2(A) or (B). In this case $e_e = x_3/L$.

The significance of this for sleeved shafts is that if an additional compressive stress is introduced, the strain in the direction of f_1 will be greater than if f_1 acted alone, and the apparent value αE will be less than the true value E.

Application of restraint of strain

To use this idea in the equation for moment of inertia of a composite shaft, I_e must incorporate the apparent value of the modulus, αE. In other words, the shaft stress caused by bending of the beam, and stress caused by the radial interference, must be taken into account. To illustrate this point further, consider Fig 3(A), a typical sleeved-shaft assembly with a cast iron sleeve and symmetrical loading, which is usually cored to produce two mating surfaces for the shaft. The interference fit is achieved by freezing the shaft so that it contracts sufficiently to enter the sleeve.

First determine the equivalent moment of inertia for the composite sections, Fig 3(B). For the center section

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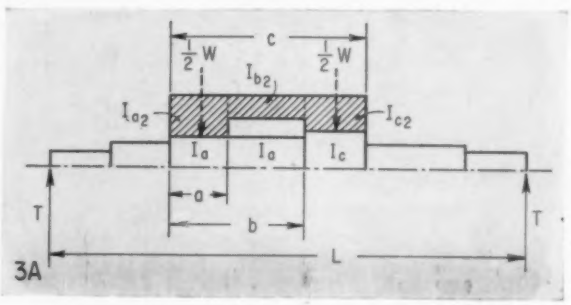
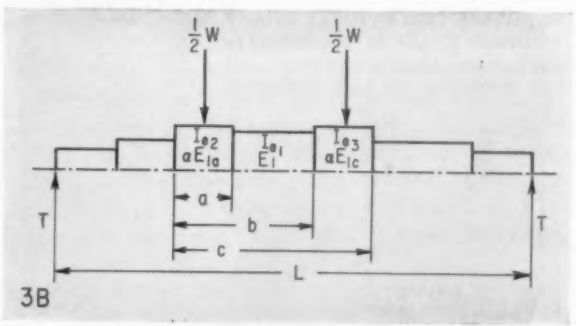
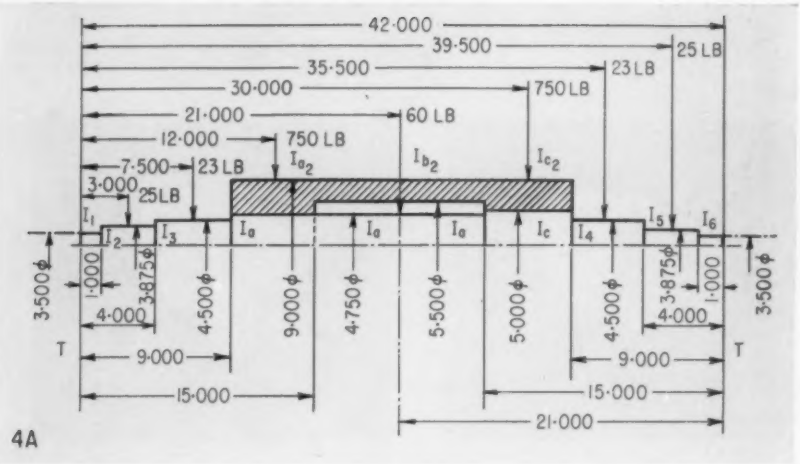




SHAFT WITH CAST IRON SLEEVE (A) can typically be replaced with equivalent shaft (B).

DEFLECTION OF SLEEVED SHAFTS

continued

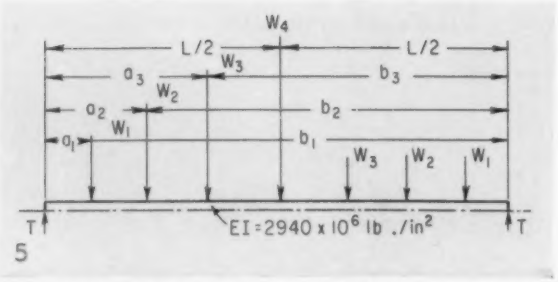


4A

	21·000 / 15·000 / 9·000 / 4·000 / 1·000					21·000 / 15·000 / 9·000 / 4·000 / 1·000				
	E_1, I_1	E_1, I_2	E_1, I_3	I_{e_2}, aE_{1a}	E_1, I_{e1}	E_1, I_{e1}	I_{e_3}, aE_{1c}	E_1, I_4	E_1, I_5	E_1, I_6
Section	A	B	C	D	E	F	G	H	J	K
I in^4	7.366	12.57	20.13	288.9	154.1	154.1	293.1	20.13	12.57	7.366
$E/10^6$ lb/in^2	30	30	30	15.75	30	30	15.5	30	30	30
$EI/10^6$ lb-in^2	22.09	377.1	603.9	4550	4620	4620	4540	603.9	377.1	22.09
x in	1	4	9	15	21	21	15	9	4	1
y in	0	1	4	9	15	15	9	4	1	0
x^3 in^3	1	64	729	3375	9261	9261	3375	729	64	1
y^3 in^3	0	1	64	729	3375	3375	729	64	1	0
$x^3 - y^3$	1	63	665	2646	5886	5886	2646	665	63	1
$(x^3-y^3)/EI$	0.045	0.167	1.10	0.582	1.26	1.26	0.583	1.10	0.167	0.045
$K_1 = 3.154/10^6$						$K_2 = 3.155/10^6$				

4B

SOLUTION FOR TYPICAL SHAFT ASSEMBLY (A) is simplified by finding the equivalent shaft (B) and tabulating the various factors.



5

IN LAST STEP before calculating deflection, a shaft with equivalent-uniform modulus of elasticity replaces the shaft with discontinuous modulus.

("bridge portion") it is evident that the sleeve will not bend to the same radius of curvature as the shaft section under it. Nevertheless, since the sleeve and shaft are rigidly connected at the mating surfaces, the error involved in assuming the composite-beam theory for this section will not be appreciable. On this basis the equivalent moment of inertia for this section is:

$$I_{e1} = I_a + mI_{b2}$$

For the other two sections with interference fit between shaft and sleeve it is necessary to determine the apparent moduli of the shaft, aE_{1a}, aE_{1c}. This gives an apparent modulus ratio $am = E_2/aE_{1a}$; $am = E_2/aE_{1c}$ and from this equivalent moments of inertia of the composite sections are:

$$I_{e2} = I_a + \alpha m I_{a2}$$

dna $$I_{e3} = I_e + \alpha m I_{e2}$$

The equivalent moment of inertia and apparent modulus of elasticity for each of the sleeve sections is indicated in Fig 3(B). The other sections shown are unaffected by the interference fit of the sleeve, and their analysis is considered by the usual methods.

Procedure for obtaining equivalent shaft

The method described above can be summarized in the following eight steps:

1. Calculate the equivalent inertia I_{e1} for the bridge portion of the assembly.

2. Calculate the bending moment for each affected section, using usual methods.

3. Calculate the stress caused by bending f_1 at each seating, using the equation for simple bending:

$$f_1 = (M/I)r$$

where I is the equivalent moment of inertia (I_a or I_e) for each seating where sleeve fits.

4. Calculate the strain caused by bending at each section (i.e. $e_1 = f_1 E_1$).

5. Calculate the interference stress f_2 for each section, using the following equation based on theory of thick cylinder (see *Strength of Materials*, S. Timoshenko, Vol II, p 210):

$$f_2 = (E_2\delta/2R^2r)\ (R^2 - r^2)$$

6. Determine the strain in the direction of the bending stress caused by the complex stress system. This can be done by using the general equation for strain in a two-dimensional stress system described above, remembering that since f_2 is compressive, it must carry a negative sign. The general equation is:

$$e_c = (1/E_1)\ (f_1 - \lambda f_2)$$

7. Using e_c from above, calculate the apparent modulus of elasticity for each section, αE_{1a} or αE_{1c} (i.e. $\alpha E = f_1/e_c$).

8. Calculate the equivalent moment of inertia for each section, I_{e2} and I_{e1}, using the modulus of elasticity from step 7 above. The deflection then can be calculated in the normal manner for beams of nonconstant flexure.

Example

Suppose it is required to determine deflection and critical speed of a shaft-and-sleeve assembly, Fig 4(A). The various loads, including the weights of the shaft and sleeve, are assumed to result in the symmetrically loaded system shown. The modulus of elasticity for the steel shaft is $E_1 = 30 \times 10^6$.

The moment of inertia for each section can be obtained from standard tables as follows:

$$I_1 = I_6 = 7.366;\ I_2 = I_5 = 12.57;\ I_3 = I_4 = 20.13$$
$$I_a = 24.99;\ I_e = 30.68$$
$$I_{a2} = 297.04;\ I_{31} = 277.11;\ I_{e2} = 291.35$$

The equivalent shaft of nonconstant flexure, Fig 4(B), can now be obtained by the procedure described above.

1. Equivalent moment of inertia for bridge section:

$$I_{e1} = I_a + mI_{b2}$$
$$= 24.99 + (14/30) \times 277.11 = 154.1 \text{ in.}^4$$

2. Bending moments at center of each seating for this symmetrically loaded system are equal and the reaction at each bearing will be half the total load on the assembly:

$$T = 25 + 23 + 750 + 30 = 828 \text{ lb}$$

This gives equal bending moments at center of each seating:

$$M = (828 \times 12) = (25 \times 9) - (23 \times 44.5) = 9607.5 \text{ lb-in.}$$

3. Bending stress at each seating:

$$f_{1a} = (M/I_a)ra = (9607.5/24.99) \times 2.375 = 912 \text{ lb/in.}^2$$
$$f_{1e} = (M/I_e)rc = (9607.5/30.68) \times 2.50 = 775 \text{ lb/in.}^2$$

4. Strain resulting from bending stress at each seating:

$$e_{1a} = f_{1a}/E_1 = 912/30 \times 10^6 = 30.4/10^6$$
$$e_{1e} = f_{1e}/E_1 = 775/30 \times 10^6 = 25.83/10^6$$

5. Interference stress at each seating: Assuming an interference fit of about 0.001 in. per in. of shaft diameter, the diametrical interference is 0.0025. This gives:

$$f_{2a} = (E_2/\delta\ 2Ra^2ra)\ (Ra^2 - ra^2)$$
$$= (14 \times 10^6 \times 0.0025/2 \times 81 \times 4.75)\ (81 - 20.25)$$
$$= 2760 \text{ lb/in.}^2$$
$$f_{2c} = (E_2\delta/2\ Rc^2rc)\ (Rc^2 - rc^2)$$
$$= (14 \times 10^6 \times 0.0025/2 \times 81 \times 5)\ (81 - 25)$$
$$= 2420 \text{ lb/in.}^2$$

6. Strain in direction of bending caused by complex stress:

$$e_{ca} = (1/E_1)\ (f_{1a} - \lambda f_{2a})$$
$$= (1/30 \times 10^6)\ (912 + 0.3 \times 2760) = 57.9/10^6$$
$$e_{cc} = (1/E_1)\ (f_{1c} - \lambda f_{2c})$$
$$= (1/30 \times 10^6)\ (775 + 0.3 \times 2420) = 50.3/10^6$$

In the above equation f_{2a} and f_{2c} are negative and therefore the resulting stresses are additive.

7. Apparent modulus of elasticity:

$$E_{1a} = f_{1a}/e_{ca} = 912 \times 10^6/57.9 = 15.75 \times 10^6 \text{ lb/in.}^2$$
$$E_{1c} = f_{1c}/e_{cc} = 775 \times 10^6/50.03 = 15.5 \times 10^6 \text{ lb/in}^2$$

8. Equivalent shaft:

$$I_{e2} = I_a + \alpha m\, I_{a2} = 24.99 + (14/15.75) \times 297.04$$
$$I_{e3} = I_e + \alpha m\, I_{e2} = 30.68 + (14/15.5) \times 291.35 = 293.2 \text{ in.}^4$$

Deflection of a shaft with discontinuous flexure can be determined by any of several methods, the graphical method using the conjugate-beam theory being perhaps the most popular. The strain energy method, however, replaces the system of varying flexure with one of constant flexure, as in Fig 5, and simplifies calculation of deflection.

EDITOR'S NOTE: For additional information on stress analysis, see:

New Equations for 5 Tapered Cantilever Beams, July 25 '60, p 52—Shows how economical tapered beams can be used without need to solve differential equations to find stresses and deflections.

Faster Stress Analysis of Combined Loads on Beams, May 16 '60, p 97—Author's method presents solutions to differential equations in the form of charts and easy-to-use algebraic equations. Applicable to simple beams and can be extended to beams with complex loads, as well as statically indetermine beams.

Critical Frequency of Stepped Shafts, Jan 11 '60, p 57—Gives equations for frequency and critical speed for plain, round, or tubular, rectangular stepped shafts.

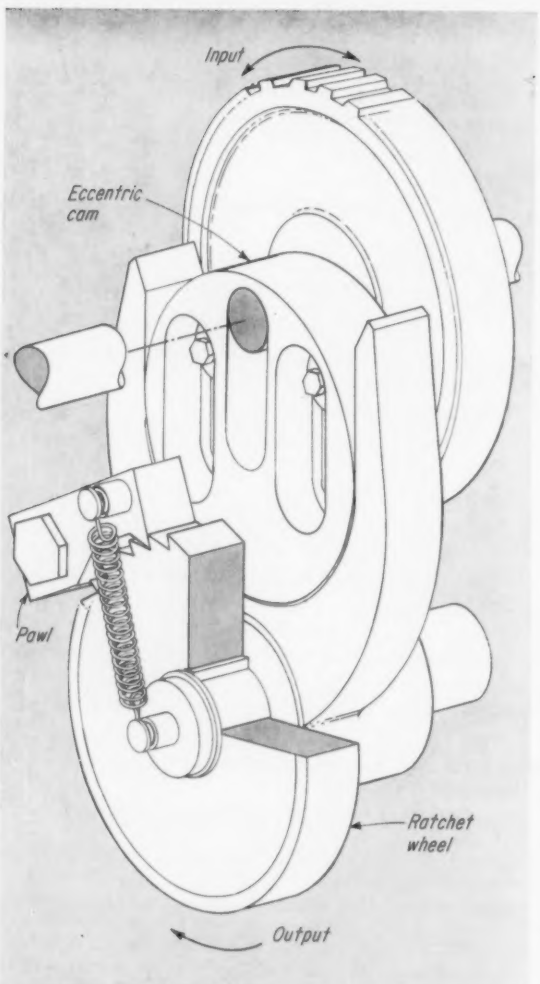
A Rundown on the Conjugate-beam Method, Aug 18 '58, p 83—Gives four examples of application to load problems.

—Frederick Marich

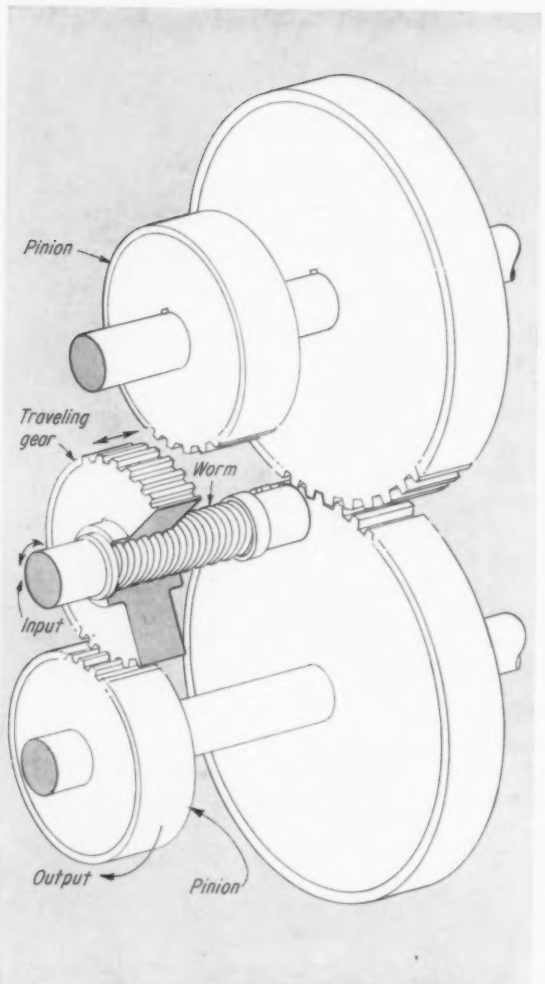
1-WAY OUTPUT FROM SPEED REDUCERS

When input reverses, these 5 slow-down mechanisms continue supplying a non-reversing rotation.

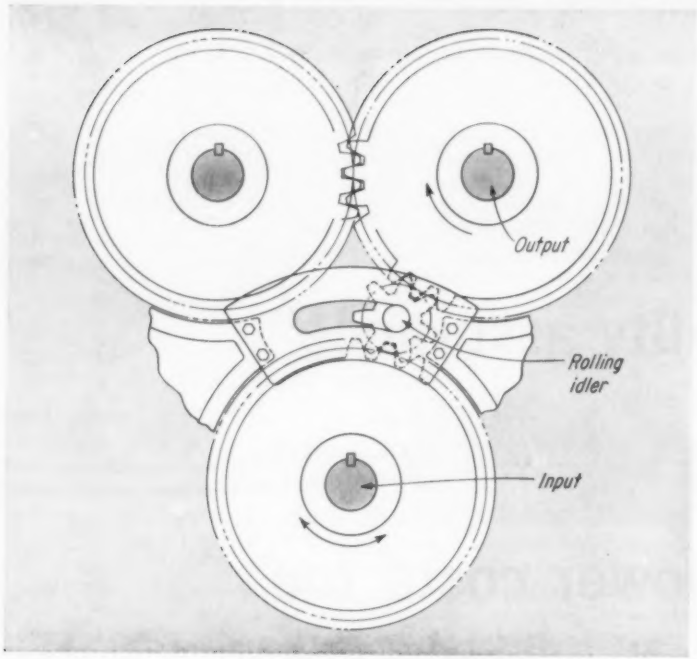
LOUIS SLEGEL
Head, Dept of Mechanical Engineering
Oregon State College
Corvallis, Ore



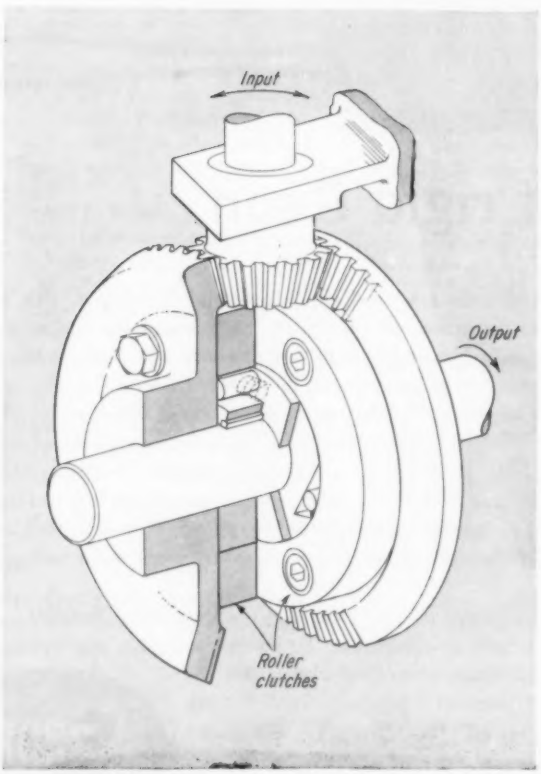
1 ECCENTRIC CAM adjusts over a range of high-reduction ratios, but unbalance limits it to low speeds. When direction of input changes, there is no lag in output rotation. Output shaft moves in steps because of ratchet drive through pawl which is attached to U-follower.



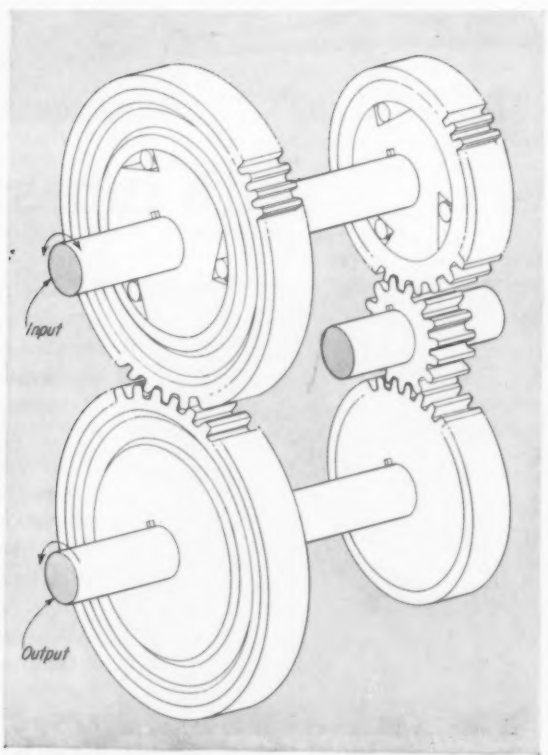
2 TRAVELING GEAR moves along worm and transfers drive to other pinion when input rotation changes direction. To ease engagement, gear teeth are tapered at ends. Output rotation is smooth, but there is a lag after direction changes as gear shifts. Gear cannot be wider than axial offset between pinions, or there will be interference.



3 ROLLING IDLER also gives smooth output and slight lag after input direction changes. Small drag on idler is necessary, so that it will transfer into engagement with other gear and not sit spinning in between.



4 TWO BEVEL GEARS drive through roller clutches. One clutch catches in one direction; the other catches in the opposite direction. There is negligible interruption of smooth output rotation when input direction changes.



5 ROLLER CLUTCHES are on input gears in this drive, again giving smooth output speed and little output lag as input direction changes.

B.F.Goodrich

"Quality assurance"

and lower costs, too

with tubes of rigid Geon

FAST tubular capacitors encased in tubes made of rigid Geon are manufactured by John E. Fast Company, Chicago. Picture shows test operation. Special attention is paid to humidity, even to the clothes and cosmetics operators wear. 100% of production is tested to provide constant information on product quality Tubes are extruded by Pyramid Plastics, Chicago, of rigid Geon supplied by B.F.Goodrich Chemical Company.

Because his capacitors are used in "Minuteman" missiles, this manufacturer pays extra attention to already high standards for reliability. He aims to a quality level 50 times better than normal industry goals. Maintaining this kind of quality can be costly. Instead, careful analysis of components which led to replacing paperboard tubes with tubes of rigid Geon vinyl helped improve reliability and cut costs at the same time.

The rigid Geon tube gives excellent dielectric characteristics. It assures that the case will never be the cause of a humidity problem. It will not corrode or be adversely affected by aging. The manufacturer has also found that rigid Geon tubing is easy to work with in assembly operations.

Here's another place where Geon vinyl is improving products, sometimes opening whole new markets. To learn about this and applications of Geon in other forms, write Department NO-3, B.F.Goodrich Chemical Company, 3135 Euclid Avenue, Cleveland 15, Ohio. In Canada: Kitchener, Ontario.

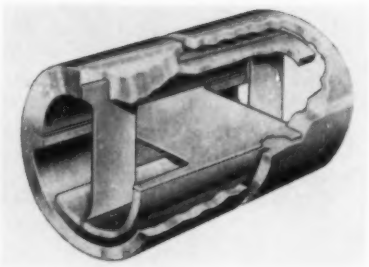
Geon VINYLS

REG. U.S. PAT. OFF.

B.F.Goodrich Chemical

a division of The B.F.Goodrich Company

SIGNIFICANT COMPONENTS MATERIALS, PROCESSES



Flexural pivot . . .
designed to take place of ball bearing assemblies and jewels, is a less bulky cross-spring pivot that has flat steel springs forming a sort of web between two separated "halves" of a tubular bearing. Their flexing allows movement—up to a 60° arc—with no rubbing of one part against another. Needs no close-tolerance machining of mating parts for installation, compared with standard ball bearing unit. Also, no contamination problem is said to occur in either manufacture, storage or operation of the nonfriction bearing. Available in two types: cantilever model to support an overhung load and a double-end support model to bridge-support a central load. In pivot, two concentric cylindrical sleeves with cutaway sections are interconnected by two flat crossed springs. Outer sleeve is separated into sections along main longitudinal axis to permit relative rotation within specified range. Pivot is used as a bearing by securing linkage arms of load to each section of outer sleeve. In cantilever type, one end can be rotated relative to other end, while in second model, two ends are connected and can be rotated relative to center sections. Diameters available in both types include: $\frac{5}{32}$, $\frac{7}{16}$, $\frac{5}{16}$, $\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$ and $\frac{3}{4}$ in. Priced at approx $6. **Utica Div, Bendix Corp, 211 Seward Ave, Utica, NY.**

Circle 300 on Reader Service Card

Diaphragm pressure switches
hold accuracies within 0.5%, compared with usual 1%. (Accuracies to within 0.2% available on request). Have interchangeable components—contact elements, capsules, and terminal block and explosion-proof housings—which are attached to standard bodies. This paves way for cost-cutting mass-production methods and allows wide variations in design (only elements desired need be ordered). Proof pressures to 600 psi and adjustable ranges from vacuum to 400 psi are supplied, making it possible to use inexpensive diaphragm pressure switches on installations that normally require high-priced bourdon tube models. Housings are independent of sensing and switching mechanisms, minimizing effect of wide temperature changes. Standard pressure connection is $\frac{1}{4}$-in. NPT female pipe fitting. However, $\frac{1}{2}$-in. fittings suitable for mounting directly on $\frac{1}{2}$-in. pipe can be supplied on request. Prices range from $19 to $27; delivery in 1 wk to 10 days. **Barksdale Valves, 5125 Alcoa Ave, Los Angeles 58.**

Circle 301 on Reader Service Card

Miniature photocell . . .
differing from photoconductor or photovoltaic types, is a light-actuated PNPN silicon switch with an impedance of over 10 megohms when "off" and under 10 ohms when triggered "on" by light. Output is determined primarily by load and is independent of light input at all intensities above triggering level. Although measuring 0.185 in. dia x 0.200 in. long, unit delivers up to 300 ma load current at up to 200 v with efficiency of more than 98%. Can permit direct actuation of a load without intermediate relays, amplifiers, mag amps or similar elements. Priced between $9 and $33 each in quantities of 100. From stock in small quantities. **Solid State Products Inc, 1 Pingree St, Salem, Mass.**

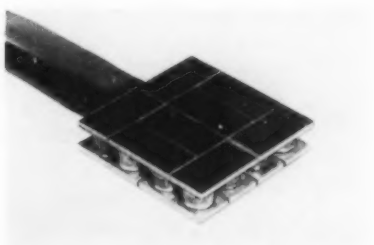
Circle 302 on Reader Service Card

Epoxy-silver solder . . .
can be used at low temperatures for components which are heat sensitive, and has no flux or residue to contaminate sensitive electronic components. Resistivity is said to approach resistance of metals—between 0.1 and 0.0001 ohms-centimeters. Makes strong (reportedly topping usual metal solders), conductive bond with most materials. Shear strength of a steel-to-steel bond is stated at 3200 psi. When bond hardens, it can be plated with conventional plating techniques and soldered if desired. Available in two paste forms—a one-component heat curing (as low as 257 F) paste and a two-component room temperature cure paste. A 3-oz sample quantity is priced at $10. Other quantities, furnished in 2- and 1-oz containers, are priced from $2.50 to $3 per oz. From stock. **Epoxy Products Inc, 137 Coit St, Irvington, NJ.**

Circle 303 on Reader Service Card

Illuminated indicator switch
said to cost two-thirds less than other indicator switches, accepts 5000-hr lamps in 4-, 6-, 10-, 12-, 16-, 24-, 28- and 48-v sizes. Change in circuit merely requires a change in lamp, which can be accomplished from the front. Nylon pushbutton caps, which also can be replaced without special tools from front of mounting panel, are available in red, yellow, green, white and blue, with letters and numbers or special legend designations on request. Switch, a SPDT unit, has four wiping contacts for separate indicating and load circuits and is rated at 5-amp capacity at 250 v. The spring-loaded mechanism has a one-million index life. Measuring $\frac{41}{64}$ in. in dia, black nylon switch comes individually packed, 50 units to standard case. From stock at $4.40 each with quantity discounts. **Sylvania Lighting Products, 60 Boston St, Salem, Mass.**

Circle 304 on Reader Service Card

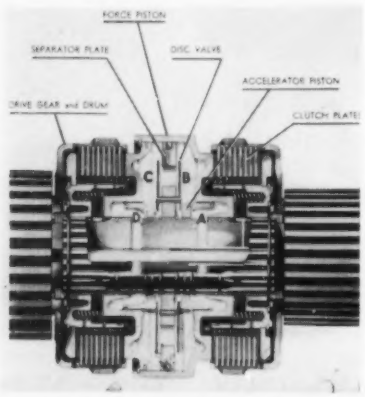


Thermoelectric components . . .
spot-cool "black box" circuits, overheated by heat dissipation of power transistors and similar heat-generating electronic parts. Available as an array made of several smaller junctions or as a finished module with $\frac{1}{8}$-in. aluminum plates on top and bottom. Single module, measuring $1\frac{1}{4}$ x $1\frac{1}{4}$ x $\frac{1}{4}$ in., pumps more than 20 w and typically attains a temperature differential between hot and cold plates of more than 176 F. Capacities are said to be even

continued on page 68

greater when several modules are connected in series or parallel. Array is priced at $85.19 each in quantities of 1 to 24; $68.15 each in quantities of 25 to 99; and $56.79 each in quantities of 100 to 999. Module prices are: $91.06 each in quantities of 1 to 24; $72.85 each in quantities of 25 to 99; and $60.71 each for 100 to 999 units. From stock. **Ohio Semiconductors, 1205 Chesapeake Ave, Columbus 12, Ohio.**

Circle 305 on Reader Service Card



Dual-drive hydraulic clutches

provide automatic torque modulation—or gradual pressure buildup—for cushioned starts under any load and for longer clutch and driveline life. Clutches transmit only enough torque to complete a shift, then continue to max capacity. They shift and engage in less than 0.6 of a sec. When disengaged, clutch cavities are under constant lube oil pressure, and since oil is transferred from one cavity to the other, rather than being filled and exhausted, only pressurization of these cavities is needed to fully engage clutches. Available in six sizes to handle torque loads from 1000 to 10,000 lb-ft, engines up to 1000 hp, and speeds up to 5500 rpm. **Rockford Clutch Div,. Borg-Warner Corp, Rockford, Ill.**

Circle 306 on Reader Service Card

Logic element . . .

a microminiature flip-flop, is first of six tiny devices that are expected to reduce size of a computer's logic or arithmetic section by 90% and its cost by 70%. Others to come during 1961 are a gate, half-shift register, buffer, half adder and counter adapter. They will use direct-coupled transistor logic (DCTL) circuitry and when put together as a logic section will handle logic-function requirements of digital machines operating at bit rates in excess of 1 megacycle. They will dissipate an average power of 30 milliw and operate over range of —67 to 257 F. Flip-flop, which looks externally like a standard transistor with eight leads, is introduced at $120, but price is expected to be markedly reduced as production volume increases. **Fairchild Semiconductor Corp, 545 Whisman Rd, Mountain View, Calif.**

Circle 307 on Reader Service Card

Pressure transducer . . .

offers frictionless movement for high continuous output and repeatability. Has chemical-resistant bourdon tube coupled inductively to special-design differential transformer. Case, measuring 3½ in. in dia, allows external zero adjustment and easy access to all connections. Available in pressure ranges from vacuum to 10,000 psi. Temperature limits are —115 to 500 F. **United Aero Products Corp, Columbus Rd, Burlington, NJ.**

Circle 308 on Reader Service Card

Sectional valve . . .

can have as many as eight sections, with choice of three-way, four-way, free flow or four-position float construction in each section. Handles can be mounted at either end, and load checks are provided in all sections. Anticavitation checks and either ball-spring or pilot-type relief valves are optional in one or both cylinder ports. Main relief valve—either poppet or pilot—is in left-end section, which also offers option of top or side inlet and outlet. Power beyond conversion plug, side outlet, and closed-center plug are options in right-end section. Max pressure is 2500 psi; capacity, 35 gpm. Available in ¼ to 1-in. port sizes with either straight or tapered threads. **Gresen Mfg Co, 405 35th Ave NE, Minneapolis 18.**

Circle 309 on Reader Service Card

Free-machining stainless steel

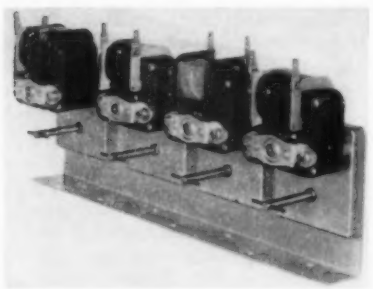
a chromium-nickel stainless called Uniloy 303MA, contains proper combination of aluminum and sulphur additives, reducing sulphur content to about one-half that of Type 303. Combination improves machinability (303MA reportedly can be machined up to 50% faster than Type 303); cuts harmful effects of high sulphur content on fabrication and performance of finished parts; improves corrosion resistance (25 times greater than Type 303 and approaching that of Type 304); and ups resistance to longitudinal splitting. Mechanical properties approximate those of Type 303—tensile strength of 95,000/100,000 psi; yield strength of 70,000/75,000 psi (0.2% offset); elongation of 40/45% in 2 in.; and Brinell hardness of 207/212. Can be arc-, flash- or percussion stud-welded and brazed when proper techniques are used. From stock in $\frac{3}{16}$ to ½-in. cold-drawn rounds; $\frac{17}{32}$ to 3½- in. centerless-ground rounds; ¼ to 2½-in. cold-drawn squares; ¼ to 1½-in. cold-drawn hexagons; and 4- and 6-in. forging billets. **Universal-Cyclops Steel Corp., Bridgeville, Penna.**

Circle 310 on Reader Service Card

Spring-loaded Teflon seals . . .

are pressure-compensated at temperatures from —420 to 500 F by their stainless steel spring inserts. Inserts are said to provide initial sealing at zero pressures, and as pressure increases, sealing force likewise increases. Springs also compensate for dimensional changes resulting from tolerance variations, thermal expansion or contraction and cold flow of the plastic. **Raco Engineering, 1650 21st St, Santa Monica, Calif.**

Circle 311 on Reader Service Card



Multiple gearmotor assembly

comprises as many as four individual subfractional-hp units fastened to a stamped steel mounting plate. Plate also serves as a cover for each motor's die-cast gear housing. Motors are available with any combination of output speeds and torque to meet specific requirements. Assembly priced at approx $16 each in production quantities. **Molon Motor & Coil Corp, 3737 Industrial Ave, Rolling Meadows, Ill.**

Circle 312 on Reader Service Card

Two-part epoxy adhesive . . .

suitable for use at room temperatures, sets in 45 sec without fuming when one drop of activator is added to two drops of base material (noncritical mixing ratio is either

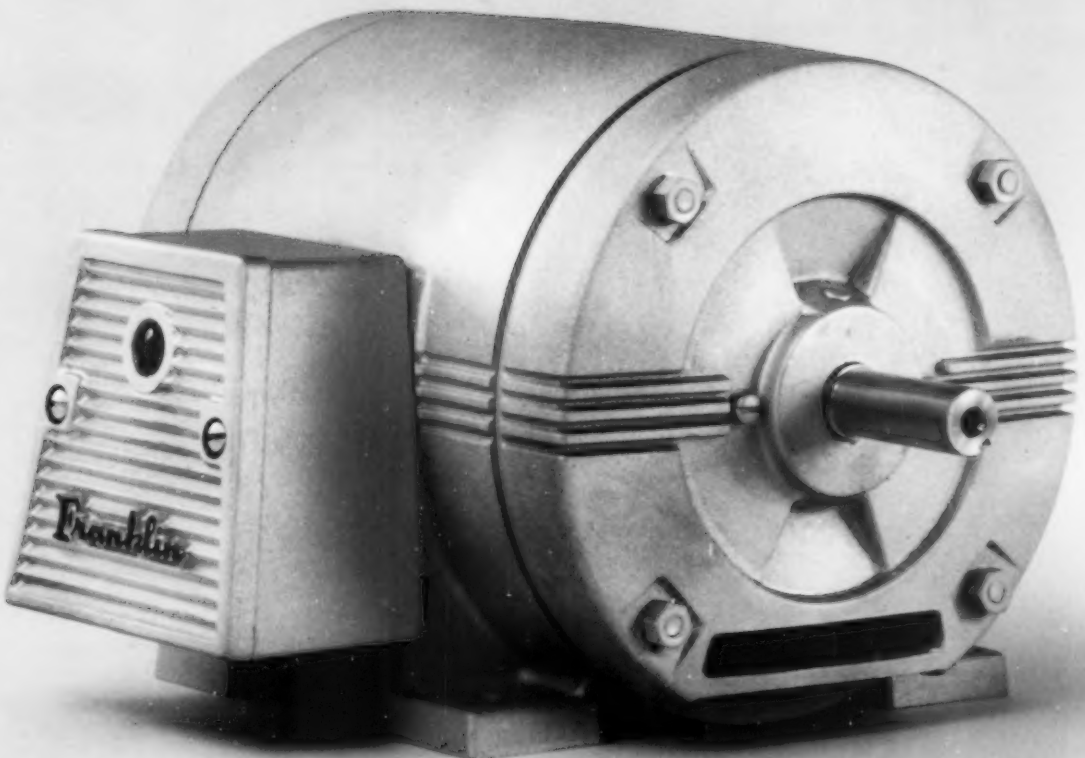
continued on page 71

CIRCLE 69 ON READER SERVICE CARD→

FROM FRANKLIN ELECTRIC

ALL-NEW STANDARD MOTORS MADE OF ALUMINUM

LIGHTER THAN CAST IRON!
STRUCTURALLY STRONGER THAN CAST IRON!

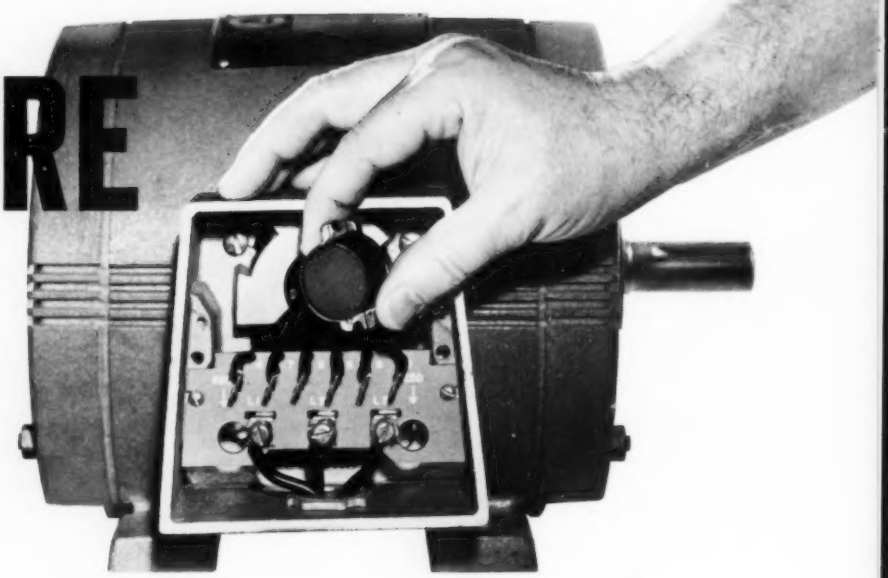


Available NOW in single-phase and polyphase, from 1 to 7½ H.P.

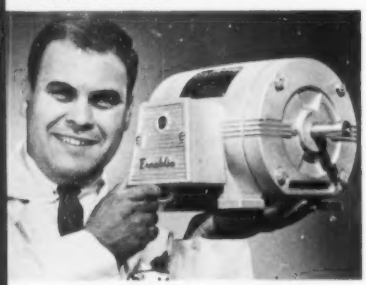
More facts available NOW on the next page...

YOU CAN'T SEE THE OVERLOAD PROTECTOR ON THIS POLYPHASE MOTOR

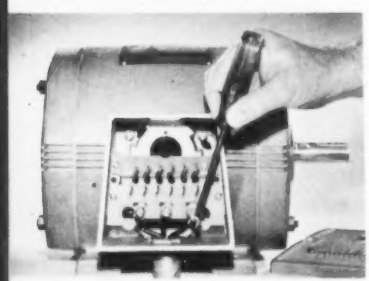
BUT IT'S THERE



Tough yet lightweight aluminum means lower shipping costs, easier assembly line handling, lower production costs.



Comes pre-wired to your specifications. Handiest terminal board design ever—just connect three line leads . . . that's all!



Burly bearing system keeps grease in the bearing for longer motor life. Bearings are prepacked and double-shielded.

The new Franklin integral is the only polyphase motor (1 to 7½ hp) designed with a built-in space for inherent protective devices. Complete motor protection, even under locked rotor conditions!

FRANKLIN—THE ONLY POLYPHASE MOTOR WITH A BUILT-IN SPACE FOR INHERENT PROTECTOR.

Inside the Franklin conduit box is a common sense idea that every engineer will appreciate. This is the *only* polyphase motor with built-in space for protector devices. Because this one built-in device protects against *all* motor burnout possibilities, even under locked rotor conditions, this new motor can be completely protected at far lower cost than ordinary motors.

The protector comes pre-installed, in exactly the right size to protect the motor under the most adverse conditions. Saves you time *and* money. Another point. The motor's appearance stays streamlined, because protectors stay where they belong —inside. Write for a free color brochure on the new Franklin integral motor.

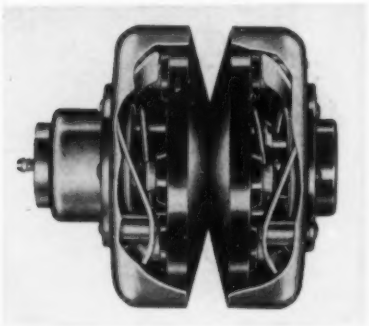
Franklin® Electric Co., Inc.

BLUFFTON, INDIANA

P-86288

by weight or volume). Provides immediate tensile shear strengths of more than 2000 psi. Adhesive system is nonflammable and has exotherm of 250 F max. Available as a syrup or petrolatum-like jelly on clear or colored and metallic pigment. Three-oz sample kits (consisting of 1 oz of activator and 2 oz of base) are from stock at $10 to $11.75. **Mereco Products Div, Metachem Resins Corp, 530 Wellington Ave, Cranston 10, RI.**

Circle 313 on Reader Service Card



V-belt pulleys . . .

have cam-control design for greater efficiency. They are rated at 1 to 5 hp at 1750 rpm and provide instantly variable ratios up to 3:1. Each pulley face is independently actuated by its own spring and cam assemblies. Opposite wedging action of each cam and cam follower prevents pulley spread, said to assure constant speed at all times, even under overload conditions. Cam action also automatically compensates for tension and alignment. Springs are not driving members but serve to keep pulley faces in contact with belt. Four models are available, using Nos 087-, 12- or 14-top width variable speed belts. Standard bore sizes are from $\frac{5}{8}$ to $1\frac{1}{8}$ in. and keyways, $\frac{3}{16}$ x $\frac{3}{32}$ and $\frac{1}{4}$ x $\frac{1}{8}$ in. Bore lengths are $2\frac{1}{2}$ to $3\frac{3}{4}$ in., max pitch dia, 5.78 to 8.62 in.; min pitch dia, 1.875 to 2.87 in.; and motor travel, $3\frac{1}{8}$ to 4 in. **Lovejoy Flexible Coupling Co, 4906-H W Lake St, Chicago 44.**

Circle 314 on Reader Service Card

Tubing inserts . . .

are two-piece welded parts for inserting in round, square or rectangular steel tubing. Stamping, with nut or screw already attached, is inserted in end of tubing and spot welded in place. Round tubing inserts are supplied for diameters from 1 to $1\frac{1}{2}$

continued on page 74

Not a worry in the world

...with *Alnor* PYROTROLLER®

positive temperature control

1. Pyrotroller—an electronic temperature controlling instrument.
2. Pyrotac—a safety excess temperature cut-out or alarm.

Dependable automatic control of temperatures in heat treating furnaces, ovens, plastic moulding, cooking vessels or for any constant temperature requirement. Operates to prevent overheating even with power failure.

The Alnor Flux Gate Sensing Coils

The simple, rugged circuitry in the Pyrotroller has a minimum of components that operate well below their rated capacities. The circuit is not critically tuned and there is no need for repeated adjustment, no shifting of the control point, no need for preselection of the one standard vacuum tube. Sapphire jewel bearings and the very high Alnor standard of precision construction makes the Pyrotroller extremely accurate particularly in the low temperature ranges.

The Alnor Pyrotroller is available in a wide range of temperatures, —100° F. through various maximum temperatures up to 3000° F. The minimum scale span is 400° F. and various ranges can be supplied to meet your particular installation. Write for complete information. Our engineering service is available on special requirements.

Alnor INSTRUMENTS

ALNOR INSTRUMENT CO.

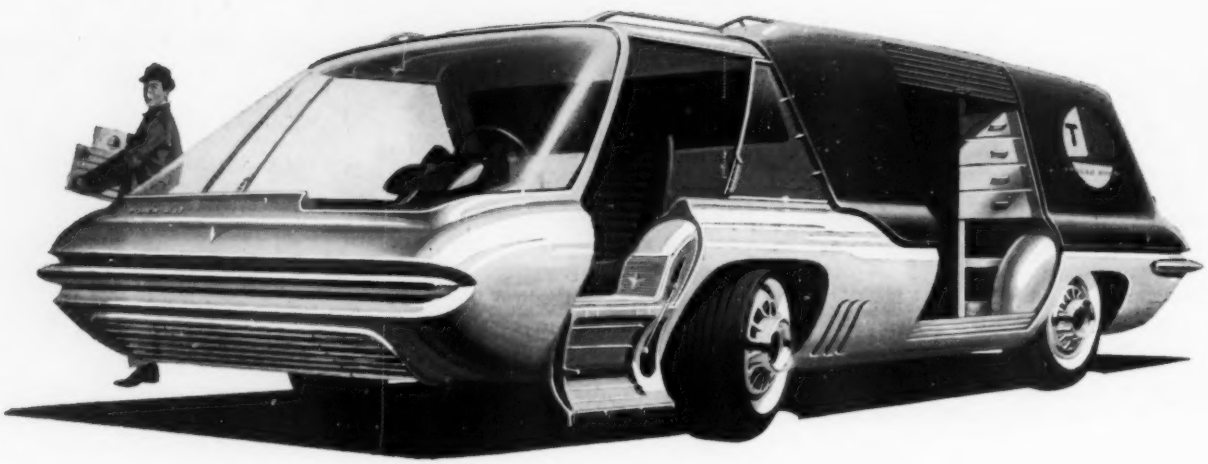
Division of **Illinois Testing Laboratories, Inc.**

Room 527, 420 N. LaSalle St., Chicago 10, Illinois

stainless steel

No other metal has the strength, beauty and versatile qualities that serve you so well today and promise so much for tomorrow.

There is nothing like stainless steel for THE AUTOMOTIVE INDUSTRY

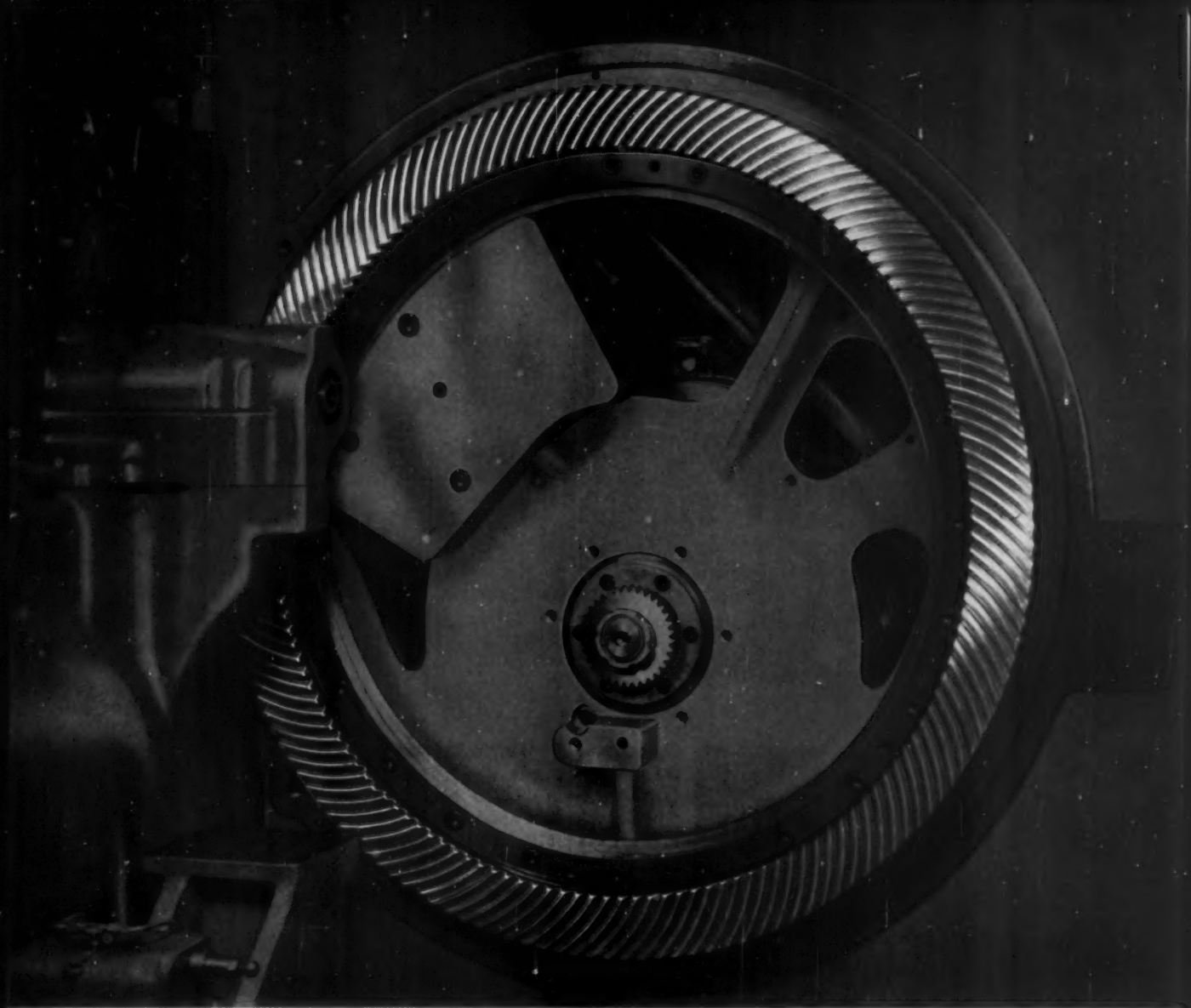


McLouth Steel Corporation,
Detroit 17, Michigan

Manufacturers of high quality Stainless and Carbon Steels

Look for the **STEELMARK** on the products you buy.

McLOUTH STAINLESS STEEL



You can get high reductions with Gleason HRH* gear sets

This thirty-one-inch gear and its pinion have a 150 to 5 ratio. Yet they are hypoids — what we call HRH or high reduction hypoids.

These compact, flexible sets can be built to ratios as high as 360 to 1 without losing the traditional advantages of Gleason design proportions.

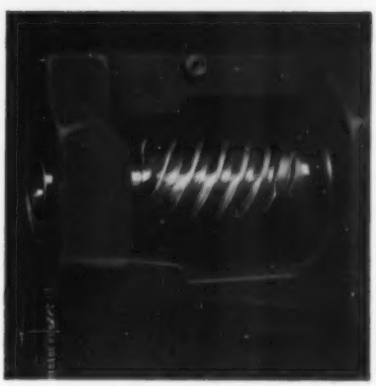
They permit you to design to tight space limits, particularly on big jobs.

They have a typically fine Gleason surface finish, impossible to get with hobbing or other methods. The pinion teeth *wrap around* the pinion, so you get continuous tooth action even with a one-tooth pinion. The resulting motion is always smooth and continuous.

You use regular Gleason machines to manufacture these gears . . . in small quantities and large.

And with all that you get the usual complete technical assistance from our engineering staff . . . all the way through the design stages on to prototypes and full production.

Find out what HRH gears can do for your transmissions by contacting us directly.



The cylindrical shape of the pinion lends itself readily to straddle mountings. The high offset design also increases the diameter of the pinion, lending extra strength to the entire assembly.

*Trademark for Gleason High Reduction Hypoids

GLEASON WORKS

1000 UNIVERSITY AVE., ROCHESTER 3, N. Y.

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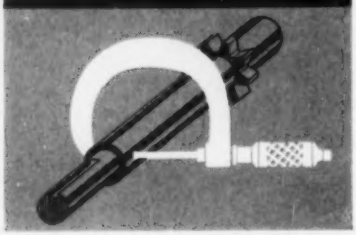
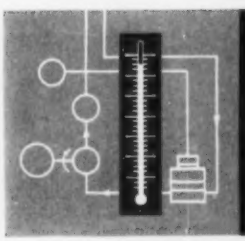
CIRCLE 73 ON READER SERVICE CARD

BERRY/DOWTY* gear pumps

One million cycles without measurable wear



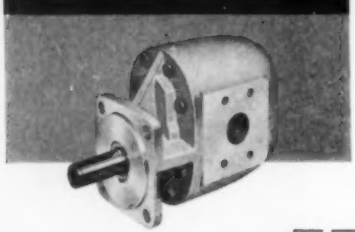
The Berry/Dowty line of hydraulic gear pumps has been subjected to exhaustive endurance tests. A Model GPA3/170 (rated output 24.5 GPM at 1800 RPM and 2000 PSI) was put through a one million cycle 0-2000 PSI test, with the final 200,000 cycles at 230° F. There was no measurable wear as a result of this test. In this and other tests, volumetric and mechanical efficiency has increased slightly from beginning to end of test, a result of the self-compensating design.



Performance guaranteed at 230°

Performance and warranty are unaffected by system temperatures of 230° F. provided minimum operating oil viscosity is 50 SSU. Volumetric efficiencies of 95% at 2000 PSI are normal under these conditions.

Pressures to 3,000 PSI
Outputs from 1 to 85 GPM
Speeds to 6,000 RPM



Value analysis (price, performance and reliability) proves the economy of Berry/Dowty Hydraulic Gear Pumps. Wire or phone today (Corinth, Miss., ATlantic 6-5541, Dept. K) for test units for evaluation on your equipment.

Berry HYDRAULICS
A DIVISION OF OLIVER TYRONE CORPORATION

*Dowty is the trademark of Dowty Hydraulic Units Limited, England

MAIL FOR NEW GEAR PUMP CATALOG
Berry Hydraulics Corinth 1, Miss.
Name_____
Company_____
Address_____

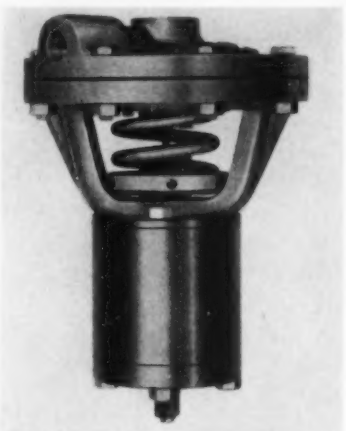
in. For square and rectangular tubing, sizes range from ⅞ to 1½ in. wide. Most popular sizes will be from stock. At present, available in 10,000-piece quantities. **Ohio Nut & Bolt Co, 50 First Ave, Berea, Ohio.**

Circle 315 on Reader Service Card

Two-way solenoid valve . .

for oil pressures to 3000 psi, has only two moving parts—poppet and plunger—making valve less susceptible to malfunction in contaminated systems. Two available types—normally open and normally closed—are pilot-operated, poppet units in cartridge form and have free reverse flow in either energized or deenergized position. Standard ac or dc solenoids are interchangeable. **Fluid Power Accessories Inc, Box 64, Glenview, Ill.**

Circle 316 on Reader Service Card



Pneumatic-circuitry valve . . .

has independently adjustable "trip-in" and "trip-out" points which vary dead band as desired. Snaps to desired porting at predetermined limits. Control signal range is 3 to 30 psig, with snap-acting mechanism operable when a min supply pressure of 10 psig is available at one or more of three body connections. No bleed of air from the three-way unit is required before or after trip. Valve body is rated at 100 psig max; operator at 75 psig max. Operates in temperatures to 180 F and has ¼-in. NPT connections with ⅛-in. internal ports. **G W Dahl Co Inc, 60 Tupelo St, Bristol, RI.**

Circle 317 on Reader Service Card

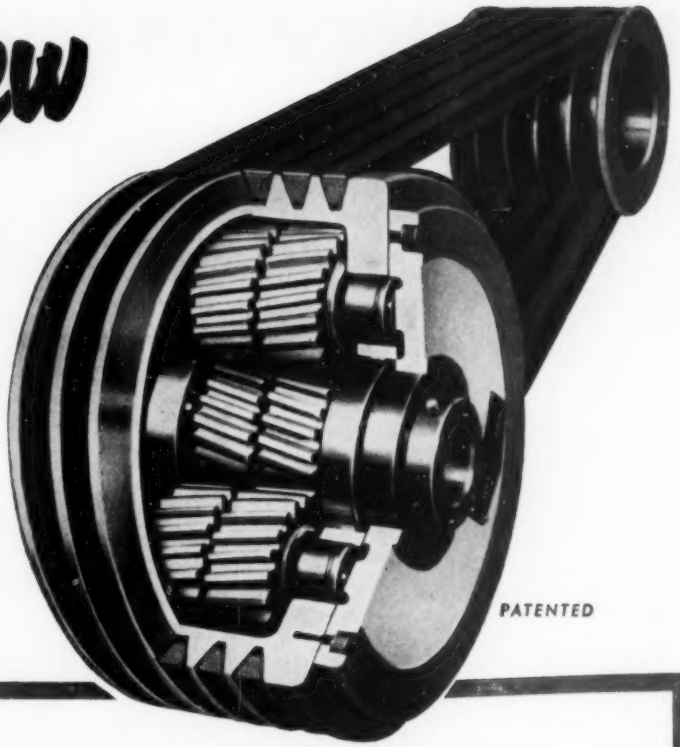
Epoxy-sealed limit switch . . .

is guaranteed for at least 10 million cycles or one year of operation. Sealing switch with thermosetting epoxy resin keeps coolants and condensates from seeping into

continued on page 78

New ROTO MISSION®

Most versatile transmission ever developed!

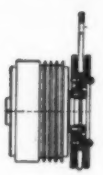


PATENTED

With these standard accessory features

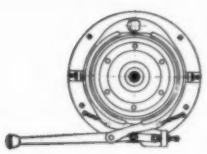
SPRING REACTION ARM

Incorporates a series of leaf springs which provide progressive overload capacity, reduce shock loading, and prevent internal damage to the unit.



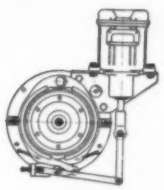
FRICTION REACTION ARM

A spring-loaded friction clutch combined with the reaction arm assembly. Designed to slip at a preselected torsional overload. Restores normal operation automatically when overload ceases.



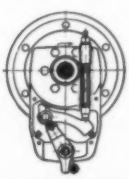
MANUAL FRICTION CLUTCH

Permits manual engagement and disengagement of the unit. Provision is made for adjusting the clutching pressure as well as compensating for wear.



ELECTROMAGNETIC CLUTCH

This modification of the manual friction clutch provides remote control of the unit by means of solenoid actuation.

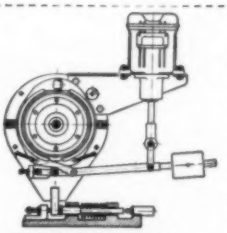


TORQUE RELEASE ASSEMBLY TYPE "A"

A mechanical attachment—integral with reaction arm—which provides complete disengagement when a preselected torque is exceeded.

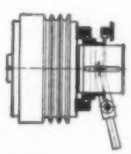
TORQUE RELEASE ASSEMBLY TYPE "B"

A mechanical attachment—separately mounted—which provides complete disengagement when a preselected torque is exceeded.



TORQUE LIMITING CLUTCH

Mechanical modification of the electromagnetic clutch assembly to provide automatic disengagement when a preselected load is exceeded.



DIRECT MESH ATTACHMENT

Permits 2-speed operation through a manually operated clutch mounted on reaction hub.

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Engineered Equipment for Aircraft and Industry

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For complete information, write for Catalog IR-61 or contact our nearest office

Designers think of R/M first for asbestos, rubber,

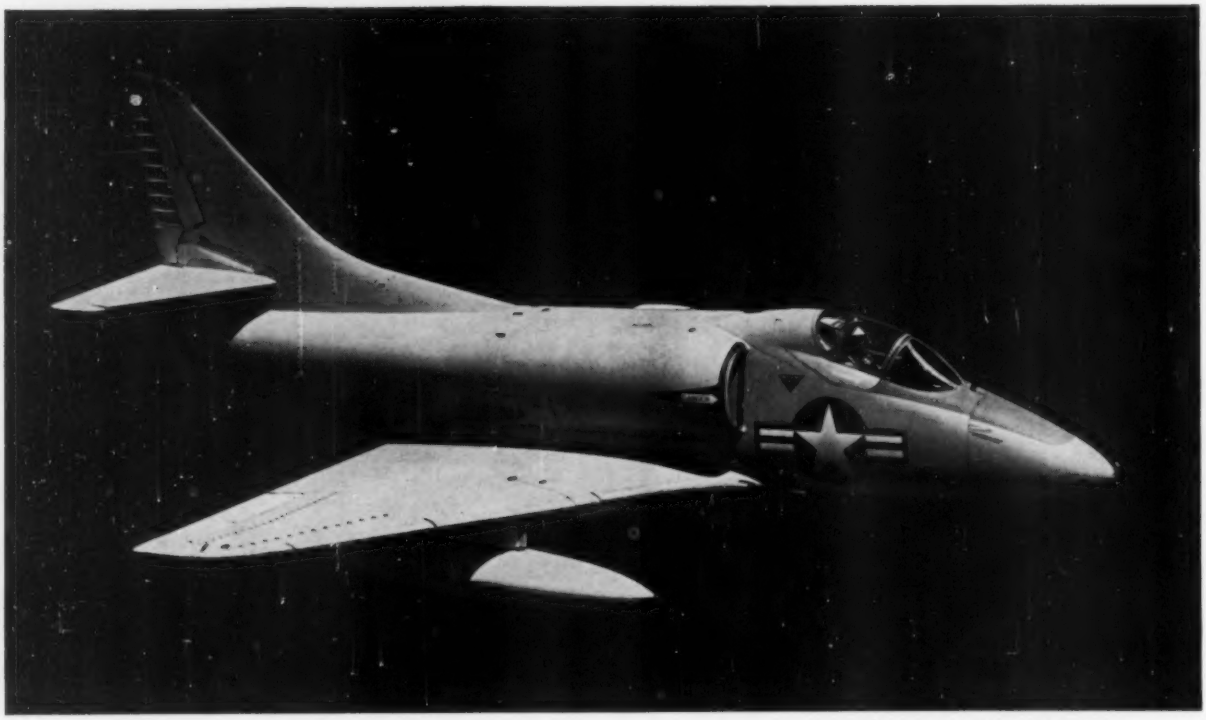

Photo courtesy Douglas Aircraft Company, Inc.

Bonded, rivetless, aluminum-cored structure of the Douglas A4D Skyhawk's rudder section prevents skin-crack failures. Conventional riveted structure could not stand pre-service load and vibration tests. Sonic flight vibration would have caused cracks between rivets on skin.

11 Ways *Ray-BOND*® Adhesives Solve Tough Fastening Problems

New bonding and laminating techniques at R/M help solve difficult fastening problems and thereby make possible many of the new products being developed and produced by America's advancing technology.

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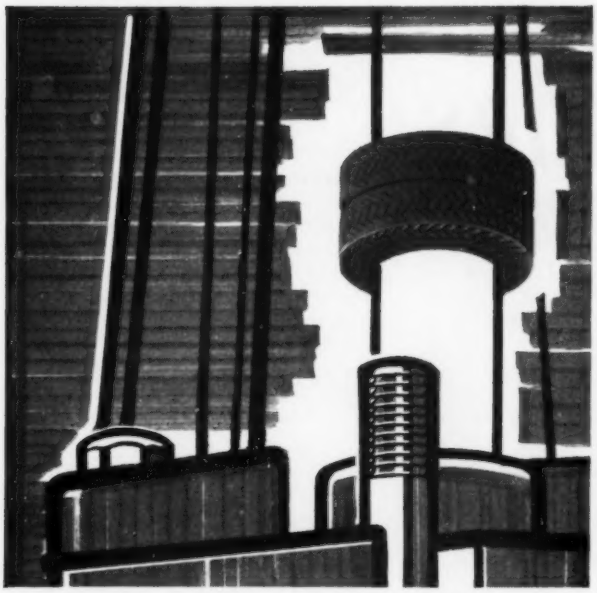
Rivets can be eliminated • Members too thin to rivet can be joined and fixed • Manufacturing costs are reduced • Life of wearing surfaces is extended • Heat conductivity is improved • Weight reduction is substantial • Load is uniformly distributed over joint area • Bond produces residual elasticity • Complex shapes can be easily fabricated • Electrical non-conductivity and protection against corrosion can be achieved • Methods of application are fast, economical, flexible

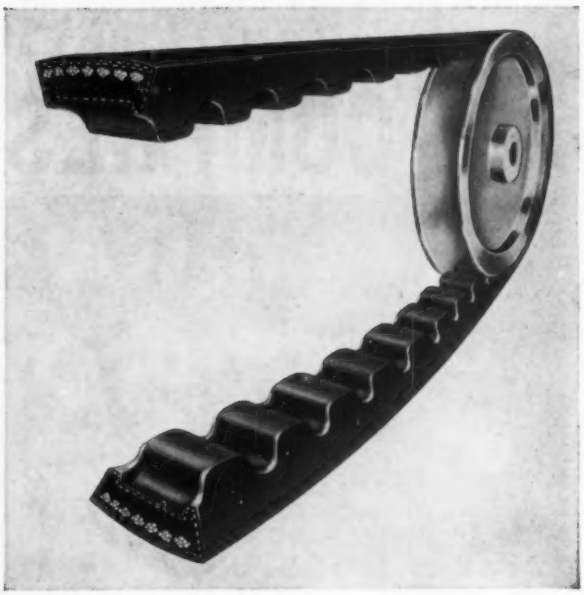
Counsel and detailed technical information regarding the selection and application of adhesives are freely available to you from Raybestos-Manhattan. An R/M representative can call on you promptly to discuss your requirements.

ADHESIVES

Get helpful engineering information on selecting, bonding and testing adhesives. Write today for your free copy of Bulletin No. 701. Adhesives Department, Raybestos-Manhattan, Inc., Bridgeport, Conn.

sintered metal, and engineered plastic products





R/M CAPABILITY PRODUCES VALVE STEM PACKING

of low volume loss at up to 1150°F

Low volume loss is a basic requirement of high-temperature valve stem packings. Reliable sealing characteristics are assured when valves are packed with R/M No. 325 because total volume loss is *less than 5%*. R/M No. 325 high-temperature valve stem packing is free of the organic materials that make other packings burn out and require much adjustment. Contains AAA grade Inconel-wire-inserted asbestos yarns braided over a plastic core that will not fuse. R/M No. 325 offers an extra dividend in that it contains a corrosion-resistant inhibitor that protects against valve stem pitting after valves are hydrostatically tested and stored.

There are R/M valve stem packings for your every department, each offering superior advantages. Let us know your requirements and depend on us to meet them.

PACKINGS

For complete information on R/M Mechanical Packings and Gasket Materials, write for new Catalog P-100. Packing Division, Raybestos-Manhattan, Inc., Passaic, N.J.

R/M CX MOLDED V-BELT OUTLASTS—AND OUTPERFORMS OTHER BELTS 8 to 1 . . .

Use R/M CX Molded V-Belts wherever more flexibility and ruggedness with quieter, cooler vibration-free operation are required.

- **Fully Molded—Fully Jacketed**
- **No Cut Notches—No Exposed Sides**
- **Holds Shape and Effective Length Without Stretch**
- **Vibration-Free—No Slap, No Hum, No Buzz**
- **No Ply Separation—No Flex-Cracking**
- **Ideal for Small Sheave Diameters, Short Centers, High Speeds**

It's the only notched V-belt of its kind made. Let R/M specialists work with you on V-belts, rubber hose, transmission or conveyor belting, molded or extruded parts.

RUBBER

Write today for Bulletin M220 and booklet shown: full details on a wide variety of industrial rubber products. Manhattan Rubber Division, Raybestos-Manhattan, Inc., Passaic, N.J.

RAYBESTOS-MANHATTAN, INC.

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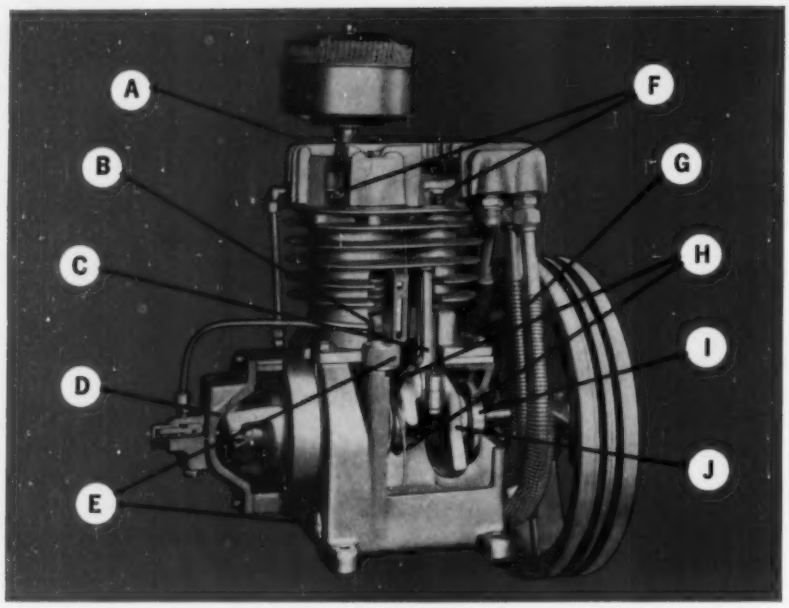
CIRCLE 204 ON READER SERVICE CARD

CIRCLE 77 ON READER SERVICE CARD

For Dependable Air Power Depend on Kellogg-American AIR COMPRESSORS

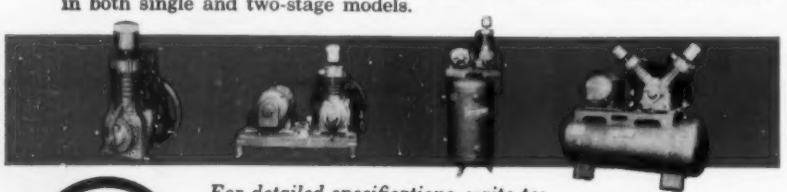


These are only a few of many quality features:

- IMPROVED HEAD DESIGN—Gives higher efficiency. Large direct air passages permit free flow of air, reducing pressure drop; greater cooling and valve areas.
- WRIST PIN BEARINGS — Roller type to withstand greater bearing load.
- CONNECTING RODS—Designed for force oiling. Automotive type insert bearings.
- CENTRIFUGAL UNLOADER—An efficient, durable device for pressure relief to insure no-load starting.
- OIL GAGE AND FILLER — Oil level is quickly checked with new look-through gage. New larger oil fill opening is located for easy, quick lubrication.
- MULTIPLE VALVES — High efficiency, wafer-type valves (with minimum of parts) have removable seats and are designed for long service life.
- IMPROVED INTERCOOLERS—Larger radiating fins. Pressure drop reduced by higher air flow capacity.
- LUBRICATION SYSTEM — Ring lubrication. Positive controlled force-feed oiling to every wearing surface.
- MAIN BEARINGS—Tapered roller bearings. Crankshaft supported at both ends.
- CRANKSHAFT — Drop-forged, counterbalanced, with super-finished bearing surfaces.

Kellogg-American's superior engineering, workmanship and rugged construction combine to assure long trouble-free life and efficient low-cost performance.

Choose from over 250 different models, from ⅓ through 20 HP, including bare compressors, base-plate mounted, and tank-mounted units. Available in both single and two-stage models.



For detailed specifications, write to:

Kellogg-American

DIVISION SCAIFE COMPANY • PITTSBURGH 35, PA.

switch housing through conduit systems. Unit also is said to be tamperproof, since switch cover is fastened to housing with drive screws. National Acme Co, 170 E 131st St, Cleveland 8.

Circle 318 on Reader Service Card

Aluminum-silicon-copper alloy

is available in solid round and hexagon-extruded shapes for use as valve stems and seats, gears, marine hardware, bushings, bearings, cams, etc. Alloy is nonmagnetic, will hot-forge and 's free-machining. Also withstands relatively high temperatures and is lightweight, and wear- and corrosion-resistant. Ampco Metal Inc, Box 2004, Milwaukee 1.

Circle 319 on Reader Service Card

Rotary switches . . .

are made in modular stages which permit them to be modified without removing them from their mountings. Stages are added by twist-to-lock bayonet principle. Each stage contains two isolated, double-break, cam-operated, silver alloy contacts that allow the ordering of only those stages needed for specific circuit requirements. Standard contact development can be arranged for 90-, 60-, 45- and 30-deg throw. Available in two models—one for 25 hp and another for 40 hp at 600 v, three-phase current. Min mechanical life of 5 million operations is guaranteed for each. Delivery in 5 to 10 days. American Solenoid Co Inc, US Hghwy 22, Union, NJ.

Circle 320 on Reader Service Card

Pressure switch . . .

used to control cut-in and cut-out pressure in high-pressure gas system, has endurance of 100,000 cycles. Models are available for pressure settings from 1500 to 3550 psi. Unit also can be used as a pressure indicator to warn whenever system pressure falls below that required for actuating equipment. Typical SPDT switch has cut-out pressure (increasing) of 3000 psi; cut-in pressure (decreasing) of 2600 psi; proof pressure, 4500 psi; burst pressure, 7500 psi; temperature range, —65 to 160 F for

continued on page 81

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Hamilton L-Contour Table
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Provide full protection, accessibility, and classification for all materials to be filed. Occupy minimum floor space.

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For practical, down-to-earth help in solving your drafting room modernization problems, consult trained POST salesmen and dealer representatives for recommendations tailored to your needs. Or, write Frederick Post Company, 3650 North Avondale Avenue, Chicago 18, Illinois, for information on the complete line of POST drafting materials and engineering supplies.

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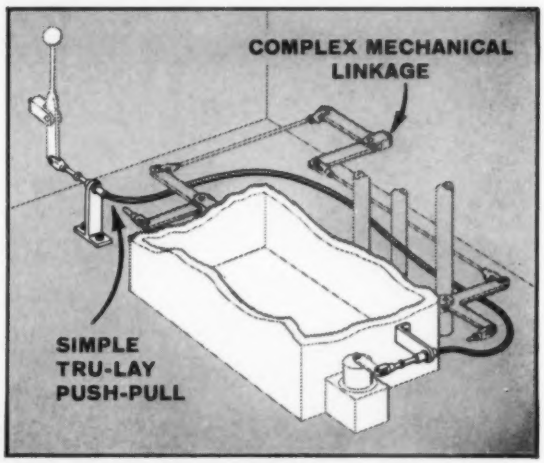
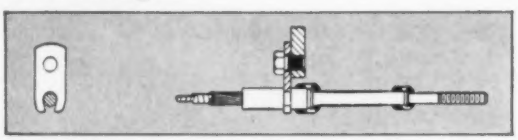
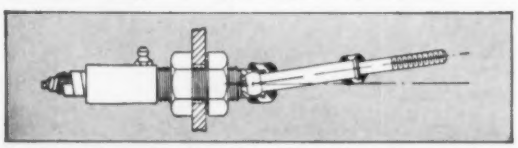


THESE FEATURES HELP SOLVE DESIGN PROBLEMS

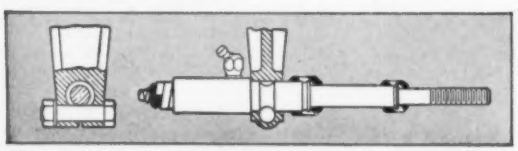
Anchorages



Clip anchorage • a simple clip for light loads

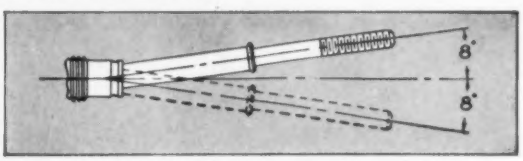


Bulkhead anchorage • for heavy-duty installations



Machined bracket anchorage • can be furnished for mounting any PUSH-PULL cable at the swivel terminal

Swivel Action



Standard assemblies have end fittings with a swivel movement of ± 8° to compensate for misalignment and rise or fall of lever arms. Swivel joints, and the sliding ends, are sealed against dirt and moisture.

PUSH-PULL DATA FILE SHOWS HOW TO SIMPLIFY, IMPROVE DESIGN

• Write for your PUSH-PULL Data File. It contains a complete set of engineering bulletins which describe in detail the operation of PUSH-PULL CONTROLS, their applications, features and advantages.

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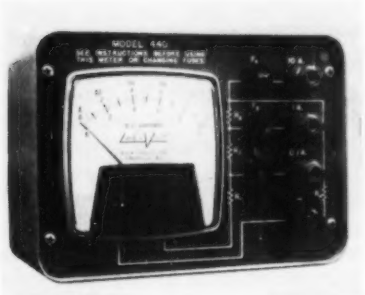
continuous duty and −65 to 250 F for intermittent duty; and electrical rating, 28 v dc, 5 amp, or 115 v ac, 3 amp. Case, sealed to withstand pressure differential of 20 psi, measures 2½ x 2⅞ x 3½ in. Weight is 0.75 lb. **Walter Kidde & Co Inc, 675 Main St, Belleville 9, NJ.**

Circle 321 on Reader Service Card

Punched-card switch . . .

provides 1000 switches in less than 0.5 cu ft. Operates from a card of 20 rows by 50 columns and has separate switch for each hole position. After card is inserted and operating lever pushed, punched holes have closed switches; unpunched holes have open switches. Switch contacts have gold plating over silver plating for long-term, reliable service. **Taurus Corp, Academy Hill, Lambertville, NJ.**

Circle 322 on Reader Service Card



Multirange electrical meters

with replaceable fuses, are said to withstand continuous overload 10 times greater than normal for 1 hr. Fuses deactivate units at less than 8 times normal load so that fuse replacement is seldom required. Full-scale accuracy is within 2%. Have 5-way binding posts, sealed mechanisms with jeweled moving parts and heavy-gage cold-rolled steel housings with wear surfaces finished in baked vinyl. Available from stock are following models: ac voltmeter in 0-5, 25 and 125-v ranges; ac ammeter in 0-2 and 10-amp ranges; dc voltmeter in 0-5, 50 and 500-v ranges; dc ammeter in 0-0.1, 1 and 10-amp ranges; and 7-purpose dc galvanometer. Prices range from $36 to $42. **Buck Engineering Co, 41 Marcy St, Freehold, NJ.**

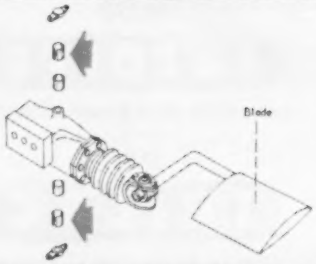
Circle 323 on Reader Service Card

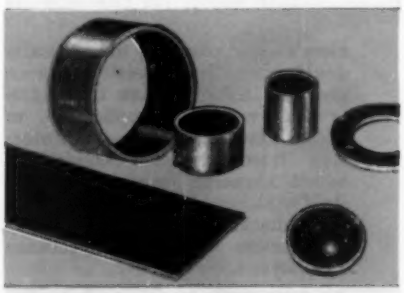
Miniature gear train servo package . . .

has three rotary elements and is available in two models. Each unit accommodates gear ratios up to 1000:1 from motor to first synchro and up to 36:1 from first to second synchro. One package measures

continued on page 83

EXAMPLE #5





DU bushings (bottom) used in the rotor assembly (center) of Navy's all-weather helicopter (top), require no maintenance, last as long as the rotor itself under severest conditions.

DU* DRY BEARINGS
Solve Another Problem

"On the basis of very successful results obtained from rigorous whirlstand testings which simulate in-flight rotor conditions, we incorporated DU bearings into production."

A. A. Coronato
Chief Component
Development Engineer
Sikorsky Aircraft Div.
United Aircraft Corp.

Used to eliminate the necessity of lubrication on the rotor damper assembly, DU bushings replace ten fittings that required daily greasing on the Navy's HSS-2 helicopter built by Sikorsky. The bushings offer satisfactory, trouble-free service for the entire life of the rotor hub despite a heavy load (1250 pounds at 203 cycles per minute, uni-directional), shock, vibration, intermittent motion and a corrosive environment.

DU metal is an ideal bearing material for many applications. It withstands much higher velocities, runs much cooler at lower speeds than other unlubricated bearings . . . has a compressive strength of 51,000 p.s.i. DU metal is applied without the need for temperature-limiting adhesives . . . will withstand from −450°F to +536°F.

GARLOCK

Apply DU dry bearings to appliances, automobiles, aircraft, farm and industrial machinery, office equipment. Standard bushings available for ¼" to 5" shafts; thrust washers for ⅜" to 2" shafts; hemispherical cups from ⅝" to 1½"; strip available for special fabrication. Write for engineering catalog DU-458. Special Products Dept., Garlock Inc., P. O. Box 612, Camden 1, New Jersey.

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LOOK FOR THE DIAMONDS—SIGN OF FINISHING QUALITY

double corrosion protection

on Aluminum, Magnesium and Zinc-plated parts

with

IRIDITE®

CHROMATE CONVERSION COATINGS

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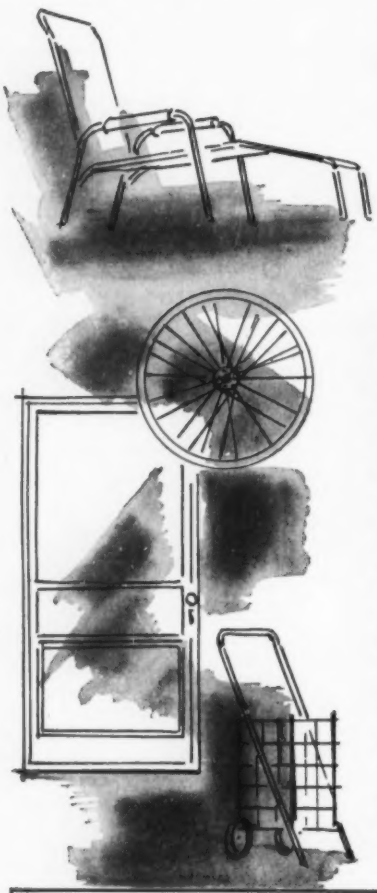
IRILAC®

CLEAR PROTECTIVE COATINGS



Here's a fast, easy way to practically double corrosion protection on your products. Simply follow the Iridite process with an application of Irilac. You give parts extra protection from corrosive conditions, added abrasion resistance, longer shelf or storage life, protection from finger marking and increased beauty for a more attractive appearance and faster sales.

ON ALUMINUM—An Iridite-Irilac finish provides long life under many service conditions. Iridite colors range from natural aluminum to golden yellow. Additional dyes give other color ranges.

ON MAGNESIUM—Irilac over Iridite 15 increases protection, resists damage from handling or abrasion. Color range—light to dark brown.

ON ZINC—Iridite plus Irilac gives longer product life, brighter appearance. Color range—clear Iridite to olive drab, plus colored dyes.

IRIDITE—chromate conversion coatings for non-ferrous metals applied by dip, brush or spray, at room temperatures manually or with automatic equipment. Provides corrosion resistance, a base for paint or decorative appearance. Forms a thin film integral with the metal. Cannot chip, flake or peel. No special equipment, exhaust systems or specially trained personnel required.

IRILAC—Clear protective coatings for all metals. Safe and easy to handle as water. Apply by dip or brush. No exhaust or special fire prevention equipment required. Adds protection and abrasion resistance to base metals, plated parts or parts treated with electrolytic or chemical post treatments without chemical change.

For complete technical information on IRIDITE or IRILAC coatings, write for FREE TECHNICAL MANUAL. Or, see your Allied Engineer. He's listed under "Plating Supplies" in the yellow pages.

Allied Research Products, Inc.

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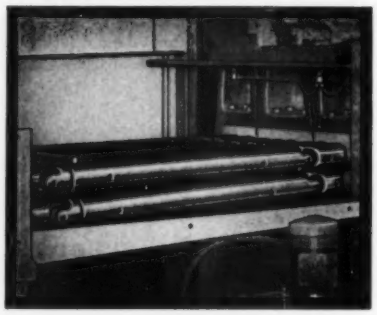
IRIDITE® Chromates | IRILAC® Coatings | ISOBRITE® Brighteners | ARP® Supplies | WAGNER Equipment

82 CIRCLE 82 ON READER SERVICE CARD

HOW CURTIS SOLVED A CLOSE CENTER-TO-CENTER PROBLEM



The close center-to-center spacing of these drive spindles on a Sutton-Maust Precision Backed-up Roller Leveler created a tough problem for its manufacturer. He needed a universal joint strong enough to stand up under heavy rolling mill conditions, yet small enough to operate at such close quarters.

The answer was a Curtis universal joint! The maximum load carrying capacity and minimum torsional deflection of the Curtis joint was found to be completely satisfactory. And Curtis' famous Telltale Lock Ring construction permits quick disassembly for easier maintenance.

This is just one of the many power transmission problems solved by Curtis universal joints — size for size the *strongest* universal joints designed for industry. Selected materials, precision engineering, and 40 years' experience manufacturing universal joints exclusively make them that way.

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14 sizes always in stock 3/8" to 4" O.D.

Not sold through distributors. Write direct for free engineering data and price list.

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CIRCLE 205 ON READER SERVICE CARD

1.75 x 1.75 x 2.25 in.; other, 1.20 x 2.50 x 2.25 in. Weighs 6 to 10 oz, depending upon materials and rotary components. **Clifton Precision Products Co Inc, 5050 State Rd, Drexel Hill, Penna.**

Circle 324 on Reader Service Card

Dual-purpose valve . . .

acts as either a quick-exhaust or double-check valve for pneumatic service. Self-contained unit operates on a pressure differential. Used as a quick-exhaust valve, it can be mounted on or near the cylinder port. The moment pressure from control valve is released, unit "dumps" exhaust air from cylinder directly into atmosphere. As double-check or "shuttle" valve, it can be used to connect two independent air supply or control lines to a common line. Suitable for two-station control, interlocking and "OR" circuitry. Measures 1¾ in. in dia, 2½ in. long and operates at pressures to 200 psi. Has three ⅜-in. NPT female ports and Neoprene diaphragm as only moving part. **Modernair Corp, 400 Preda St, San Leandro, Calif.**

Circle 325 on Reader Service Card

Plastic tubing . . .

in flexible or rigid vinyls, polyethylene, polypropylene and other thermoplastic materials, is available with up to 3-in. OD's and lengths from 3½ to 250 ft. Extruded to meet specified cross-sectional shape, wall thickness, ID and other requirements. **Petro Plastic Co, 16 Quine St, Cranford, NJ.**

Circle 326 on Reader Service Card

Fractional-hp motors . . .

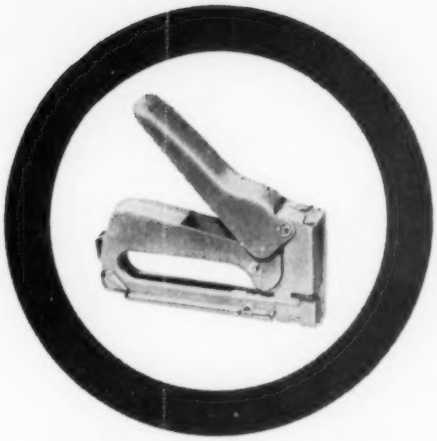
originally designed for use in lint-laden atmospheres, are totally enclosed, non-ventilated, three-phase, Form G units rated from ¼ to ¾ hp and 220/440, 220/380 and 550 v. All models are in NEMA frame size 56, while ¼-hp models are also available in size 48. Offer continuous duty operation at 131 F rise; single-shielded ballbearings that carry heavy thrust loads and are highly resistant to oxidation and moisture; and large built-in connection boxes. **General Electric Co, Schenectady 5, NY.**

Circle 327 on Reader Service Card

Servoactuator . . .

contains servoamplifier, servovalve and hydraulic cylinder and can be furnished with any stroke length from 1 to 6 in. and with cylinder diameters from 1¼ to 2½ in. Complete with built-in power

continued on page 85



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Truarc Rings cut assembly time 60%

This production advantage was achieved by Swingline, Inc., with two Truarc retaining rings: a Series 5139 Prong-lock ring and Series 5144 Reinforced E-Ring. They also saved $25 per thousand units and improved the product design by providing resilient end-play take-up . . . eliminating looseness or binding in the parts. Truarc dispensers—loaded with pre-stacked ROL-PAK® cartridges—make ring application simple, fast and economical.

Truarc Rings come in 50 functionally different types . . . as many as 97 different sizes within a type . . . 6 metal specifications and 13 finishes. Write for Catalog 10-58 which shows many specific examples of ring applications. For immediate action, call your nearest Factory Representative or Authorized Truarc Distributor. He's in your Classified Telephone Directory under: "Rings, Retaining."

1.2

WALDES TRUARC® RETAINING RINGS

WALDES KOHINOOR, INC., 47-16 Austel Place, Long Island City 1, N. Y.

9 OUT OF 10 PRODUCTS CAN BE IMPROVED WITH TRUARC RETAINING RINGS

CIRCLE 83 ON READER SERVICE CARD 83

For extreme environments!

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MICRO-PROCESSED BERYLLIUM COPPER springs

—meet these tough MARKITE 'specs'!

THE 'HEART' OF THE MARKITE POTENTIOMETER

1. A potentiometer element—embodying resistance track and take-off track of conductive plastic co-molded in an insulator base. 2. An I-S cantilever dual spring (with precious metal wipers); maintains contact with conductive tracks even under 70g vibration at 5-2000 cps, 100g shock and 100g acceleration!

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84 CIRCLE 84 ON READER SERVICE CARD

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*SMR is a special Silicone Modified Rubber produced by Stoner Rubber Company, Inc.

Photo of Rocket Chamber courtesy of Aerojet-General Corporation

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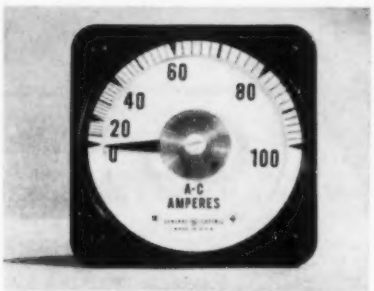
CIRCLE 206 ON READER SERVICE CARD

supply, so command can be either by potentiometer or external electrical signal. Output thrust at full piston speed is up to 5 tons; speeds are up to 40 in. per sec; and frequency response, up to 40 cps (90° lag). Integral mounting of feed back coupling is said to permit a positioning accuracy of better than 1 part in 1000. Amplifier is solid state and reportedly operates over wide temperature range. **CompuDyne Corp, Hatboro, Penna.**

Circle 328 on Reader Service Card



Ac, dc switchboard instruments . . .

have 1% accuracy range and are said to be priced 10 to 20% below other available models. Included in ac instruments are voltmeters, ammeters, frequency meters, wattmeters, varmeters, power factor meters and synchroscopes. In the dc group are ammeters and voltmeters. Convex-curved, shadowproof, molded lucite covers permit 120° readings. Scales and pointers mounted in same plane are said to eliminate paralax error, and element shielding permits mounting on magnetic or nonmagetic panels. Instruments have 180° scales. Scale length is 5.1 in. and flange diameter, 4½ in. sq. **General Electric Co, Schenectady 5, NY.**

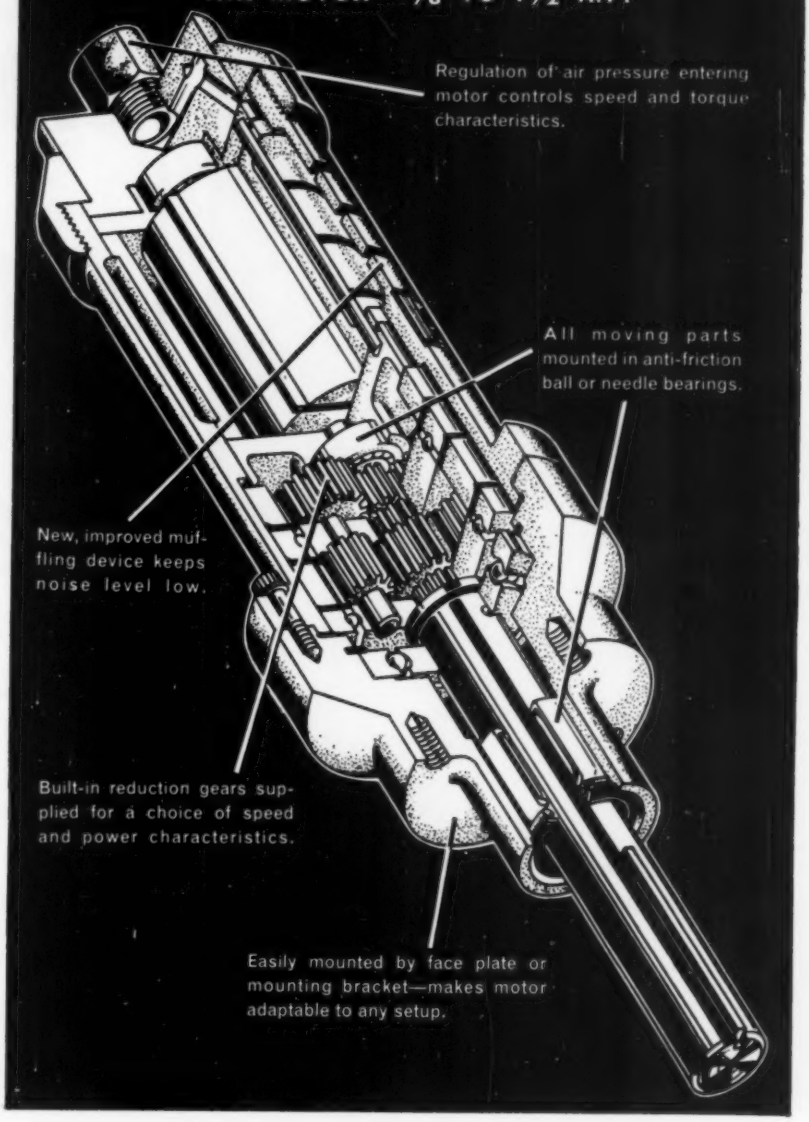
Circle 329 on Reader Service Card

Vibration- and shock-resistant motor . . .

has a cast cylindrical, non-oriented, ceramic field magnet, permanently stabilized so that it does not demagnetize in extreme temperature changes or during operation in an ac magnetic flux environment. Originally designed for government weather satellites, unit is suitable for integration and timing devices, recorders, high-speed blowers and dc servo controls. Ceramic field shields armature flux from outside electronic circuits. Can be furnished with internal RF filters to eliminate objectionable frequencies, as well as a governor to control armature speed when an application requires accuracy within 0.5% of nominal speed under wide terminal voltage and load torque variations. Unit is

continued on page 87

GARDNER-DENVER ROTARY AIR MOTOR—⅛ TO 1½ H.P.


Regulation of air pressure entering motor controls speed and torque characteristics.
All moving parts mounted in anti-friction ball or needle bearings.
New, improved muffling device keeps noise level low.
Built-in reduction gears supplied for a choice of speed and power characteristics.
Easily mounted by face plate or mounting bracket—makes motor adaptable to any setup.

Want new design ideas? Check air power

Gardner-Denver air motors offer control flexibility, vibrationless operation, high torque at any speed, freedom from overload damage and spark-free operation. And remember, Gardner-Denver products are backed by factory-trained specialists in our plants and offices throughout the world. Parts and specialized service are always available. For details, call your Gardner-Denver air power specialist, or write for air motor bulletins.

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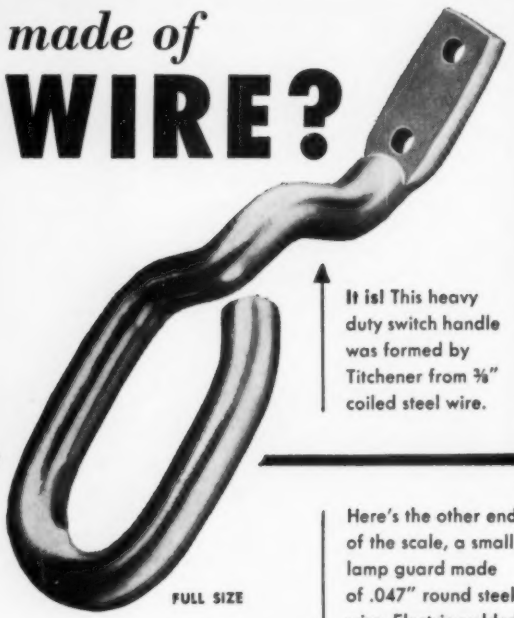
86 CIRCLE 86 ON READER SERVICE CARD

made of

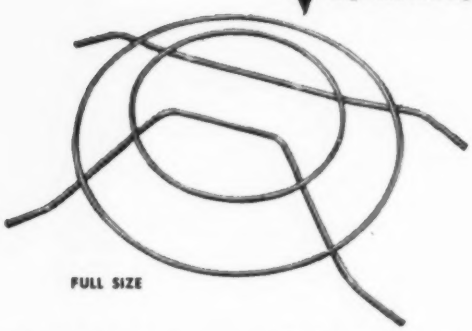
WIRE?



It is! This heavy duty switch handle was formed by Titchener from ⅜" coiled steel wire.

FULL SIZE

Here's the other end of the scale, a small lamp guard made of .047" round steel wire. Electric-welded construction — two rings and two legs.



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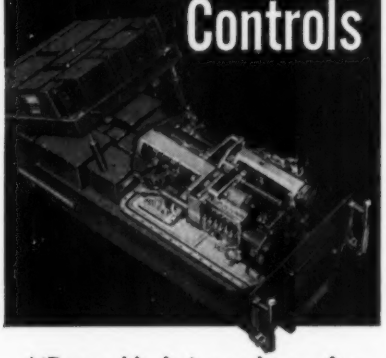
Automatic Sequencing Controls



AiResearch's design and manufacturing capability covers many types of automatic sequencing controls such as those for missile ground checkout, controlling drone and missile flight profiles, and automatic elevation and leveling of radar antennas and missiles.

Above is an AiResearch sequence controller for cabin temperature of a jet airliner. It assimilates 25 sensor element inputs and supplies command signals to 18 amplifier channels. Consisting of servo-operated potentiometer cards, cam switch programmer and other electromechanical components, it is another example of AiResearch's over-all ability to design and produce intricate and complicated servo systems.

The most experienced company in the development and production of control systems for airborne and ground use, AiResearch is an industry leader in electromechanical systems and components of all types for aircraft, ground handling, ordnance and missile systems.

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AiResearch Manufacturing Division

Los Angeles 45, California

said to be as high as 54% efficient through high flux utilization; requires very low input current at full load; and has power outputs equal to motors 50% larger. Uses axially pre-loaded ballbearings which control radial play and eliminate noise, vibration and looseness. Weighs less than 2½ oz and measures ⅞ in. in dia and less than 2 in. long. From stock at $14.50 each in quantity. Reflectone Electronics Inc, Stamford, Conn.

Circle 330 on Reader Service Card

Nylon cable clamp . . .

holds fastener captive in one arm. Installed from one side of supporting structure, clamp is secured by pressing plunger in. This action expands grommet behind supporting structure and locks the assembly. Unfastening is accomplished by lifting plunger. When clamp is prelatched prior to installation, tie wraps are not needed. Clamp supports loads up to 75 lb and can be used in temperatures from −20 to 150 F. Hartwell Corp, 9035 Venice Blvd, Los Angeles 34.

Circle 331 on Reader Service Card

Permanent-magnet dc motor . .

measuring 1 in. in dia, is available in three lengths and for use on any voltage from 6 to 115 v dc. Has explosionproof housing and square brushes, retained by a constant-pressure spring. Typical characteristics of 27-v unit include: 1 oz-in. torque; 17 mhp; 17,000 rpm; 0.85 amp; 23 w; and 53% efficiency. Electrical Components Div, Barber-Colman Co, Rockford, Ill.

Circle 332 on Reader Service Card

Snap-action relay . . .

is a plug-in, enclosed 2PDT unit, said to be priced substantially less than other plug-in assemblies. Solenoid action is positive and life of relay is limited only by snap-acting switches, each rated at 10 amp, 120 v ac; 5 amp, 240 v ac; and ½ hp at 120 or 240 v ac. Entire unit, including molded nylon enclosure but excluding pins, measures 2 1/16 x 1½ x 1 1/16 in. Eight-pin octal plug is standard. Warco Industries Inc, 569 Melville, St Louis 30.

Circle 333 on Reader Service Card

Lineal switches . . .

are said to operate through at least 50 million cycles with no measurable contact resistance. Units are sealed in molded cases which are weather impervious and provide operating range of from −60 to

continued on page 89

it's new it seals it saves

it's DELRIN*

Another RB&W development from Delrin plastic, this new threaded plug replaces more expensive metal plugs in many hydraulic and compressor applications.

It not only saves on cost and weight, but also does a better job. Fluid pressure forces mating threads together, creates a still tighter seal, locks threads in place.

Metal-like mechanical properties of Delrin provide excellent strength, dimensional stability, rigidity. Count also on resistance to corrosion and solvents.

Available in ⅛, ¼, ⅜, ½" pipe sizes. Send for samples.

Ask about other parts you would like custom-molded from Delrin, or other thermoplastics, in production quantities.

Write Russell, Burdsall & Ward Bolt and Nut Company, Port Chester, New York.

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With or without self-locking threads. Hex collar prevents turning when torqueing bolt.

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With or without self-locking threads. Centering collar positions nut and protects threads from weld spatter.

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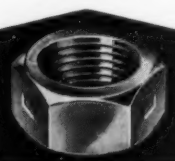

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Locking feature in the center for fast feeding. Can be applied from either end.

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With or without self-locking threads. Countersink protects threads from weld spatter.

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- Cold formed special nuts or parts to print.

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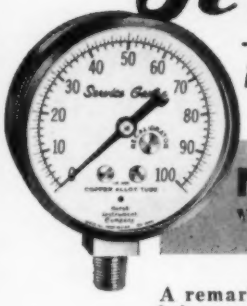

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and 30" vacuum
¼" bottom
connection.

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GAUGES • THERMOMETERS • VALVES

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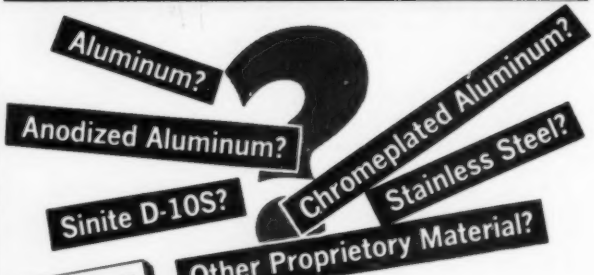

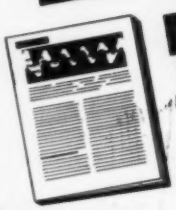

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CIRCLE 210 ON READER SERVICE CARD

250 F. Each of 16 contact arrangements is available in four different coil voltages for a total of 64 variations. Coils are 6, 12 and 24-32 v ac and 115 v dc. From stock. **Elotec Corp, 1425 N Lidcombe, El Monte, Calif.**

Circle 334 on Reader Service Card

Cable retractor . . .

for use with rack-mounted electronic equipment meets extreme environmental conditions, partially through use of a stainless steel expansion cord, and withstands temperatures from —100 to 330 F. Adjusts automatically from min to max extension and provides positive stop on return swing. Unit is made of cold rolled steel, finished with a cadmium plate and iridite dip, and all moving parts glide on a solid film lubricant. Priced at $6.95 each in quantities of 1000 and $11.60 in quantities of 1 to 10. **Vent-Rak, Dept 119, 525 S Webster, Indianapolis 19.**

Circle 335 on Reader Service Card

Precision meter . . .

is reported to be 0.025% accurate in its electrical measurements as a result of direct sampling, followed by expansion of any 10 divisions to cover a full 100-division scale. Two-step method eliminates guesswork, hunting for scales and possibility of missed readings. By electrically folding effective 5-ft scale into 10 equal sections (each 6 in. long), the third significant figure can be read exactly and the fourth figure estimated to ¼ of a division. Instrument has overload capacity of up to 125,000,000% in some cases. Available for portable or panel use. **Greibach Instruments Corp, 315 North Ave, New Rochelle, NY.**

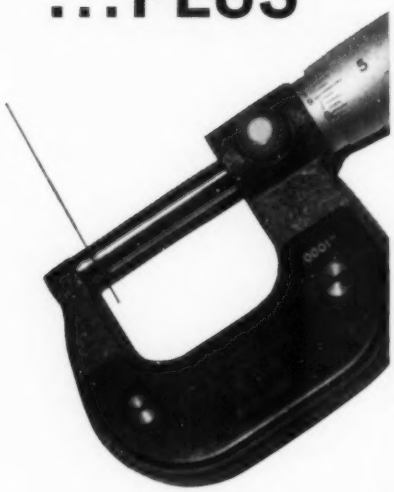
Circle 336 on Reader Service Card

Straight-cable plug . . .

for RG-188/U or other cables with similar component diameters, has crimp-on design which is said to reduce assembly time by 60% compared to clamp-on designs. Provides a screw-on connection for 50-ohm cables mating with cable and bulkhead jacks, bulkhead receptacles, cable feedthroughs, right-angle printed wiring re-

continued on page 91

TUBING
QUALITY
...PLUS



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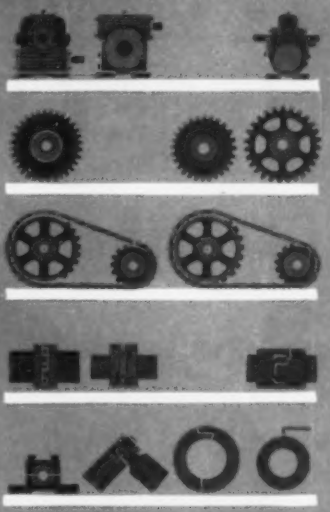

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New Rotac MIDGET Rotary Torque Actuator

Use it to lift, lower, turn, rotate, index, clamp, transfer, toggle, press, load, unload, oscillate or turnover.

Mount it vertically, horizontally, or at any angle.

Rotate or oscillate it in any arc to 270° with either keyed shaft or body rotating.

Power it with air, oil or fire-resistant fluids.

Control it with simple valving for starting, stopping, slowing-down or speeding-up.

Apply it wherever you need instant torque and controlled rotary power. Current uses include: instrument and computer designs, small parts handling, remote control of valves and switches, and other light applications.

Count on it to measure-up to your needs. New Midget Rotac is only 2" x 2" x 2", weighs just 12 ounces (single vane model), with torque ratings up to 80 inch-pounds at 300 psi input (double vane model).

Examine its design by sending today for free design data book—gives engineering data, power ratings, mounting details. Or call your Rotac Representative for details.

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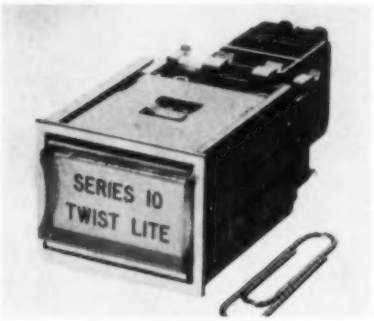
CIRCLE 90 ON READER SERVICE CARD

CIRCLE 213 ON READER SERVICE CARD

ceptacles and regular right-angle receptacles. Cable connection is made by dressing cable components, slipping a sleeve over cable, inserting cable into connector body, sliding sleeve into position and crimping with standard tool. Finished assembly is said to be stronger in pull-out strength than cable itself. Selectro Corp, 610 Fayette Ave, Mamaroneck, NY.

Circle 337 on Reader Service Card



Four-bulb switchlight . . .

can be rebulbed or color, lens or legends changed without special tools. Switches which clip to rear of unit include 2PDT and 4PDT momentary action, 2PDT alternate action, and magnetic holding. Withstands shock of 20 g's for 10 millisec in all three planes; vibration of 10 g's to 500 cps; and ambient temperatures of 159.8 F for 48 hr with all four lamps illuminated at rated voltage. Other specifications include: dielectric of 1000 v, rms min at sea level; and insulation resistance of 100 megohms min. Accepts four industry type 327 bulbs and has corrosion piercing bulb contacts. Display area can be split horizontally or vertically. Master Specialties Co, 2760 Cheryl Ann Ct, San Jose 24, Calif.

Circle 338 on Reader Service Card

Plastic fuel-filter . . .

for small engines, reportedly will not reduce fuel flow even though it traps dirt particles as small as 0.002 in. Nipple can be turned to any position around 360° by loosening a screw. Removing same screw allows filter to be taken apart for cleaning. Tillotson Mfg Co, Toledo, Ohio.

Circle 339 on Reader Service Card

Precision synchronous motor . . .

$1\frac{3}{8}$ in. in dia by $2\frac{1}{8}$ in. long, operates on 24 v, 60 cps but can be supplied with windings to operate on other voltages up to 300 v, 60 cps. With synchronous speed of 1800 rpm, motor has starting and synchronous torque of 0.70 in.-oz. Temperature limits are 0 to 140 F. Said to be commercially priced and suitable for dictating and recording devices, timers and controls or wherever constant speed drive is required. Weighs 7 oz and operates on 12.5 w. Can be reversed by switching connections. Thomas A Edison Industries, Instrument Div, 61 Alden St, West Orange, NJ.

Circle 340 on Reader Service Card

Size 11 servomotor . . .

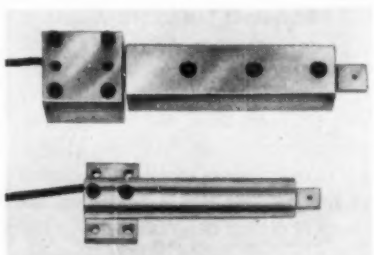
has integral friction brake controlled by an electromagnet. Spring-energized brake stops and holds rotor at desired position, preventing it from turning or "creeping" under high vibration or shock. Electromagnet, energized by 24 v dc, disengages brake, allowing motor to run. Braking time is 8 revolutions max, measured from a no-load speed of 6200 rpm. Motor operates on 115/115 v, 400 c, and is suitable for use where a motor and gearhead are mechanically coupled to a computer component. Thomas A Edison Industries, Instrument Div, 61 Alden St, West Orange, NJ.

Circle 341 on Reader Service Card

Mylar drafting film . . .

available in blue-tint or white, accommodates any ordinary graphite pencil, from H to 5H, and regular india ink. Lies flat on board; erases without leaving "ghosts"; resists tearing, cracking and abrasion; reportedly will not chip, crack, peel or wrinkle; and re-inks without feathering. B. K. Elliott Co, 536 Penn Ave, Pittsburgh.

Circle 342 on Reader Service Card

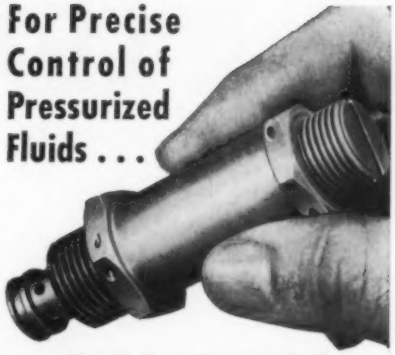


Semiconductor load cells . . .

have min of 1-v output at capacity load. Use semiconductor strain sensitive elements which form a Wheatstone bridge whose resistance change is proportional to applied load or deflection. Resolution is limited only by readout instrument. Repeatability is stated at better than 0.1%. Temperature compensation, comparable with top strain gage transducers, is less than 0.01% per deg F for thermal coefficient of sensitivity and 0.005% per deg F for thermal zero shift. Available in range from $\pm\frac{1}{2}$ to $\pm$100 lb. Kulite-Bytrex Corp, 50 Hunt St, Newton 58, Mass.

Circle 343 on Reader Service Card

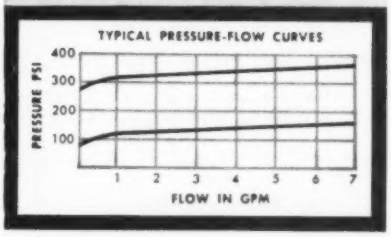
For Precise Control of Pressurized Fluids . . .



Reliable Cartridge RELIEF VALVE

- **Eliminates connectors, fittings and lines.**
- **Reduces leakage points.**
- **Simplifies maintenance.**
- **Reliable.**
- **Noiseless.**

• Simplified circuitry, reduced weight and greater design freedom are other advantages offered by this direct acting relief valve. Used in a multi-stage manifold, this valve can be removed without disconnecting any lines. It is just one of many fluid flow and pressure control valves Fluid Regulators has designed and manufactured to meet exacting specifications.



SPECIFICATIONS:

- Operating Pressure: Three ranges 75 - 500 psi
- Burst Pressure: Above 5,000 psi
- Cracking Pressure: Externally adjustable
- Internal Leakage: Drops per minute
- External Leakage: Zero
- Fluids: All fluids compatible with stainless steel and anodized aluminum
- Temperatures: −65°F. to +275°F.
- Weight: 6 oz.
- Part No.: 7385

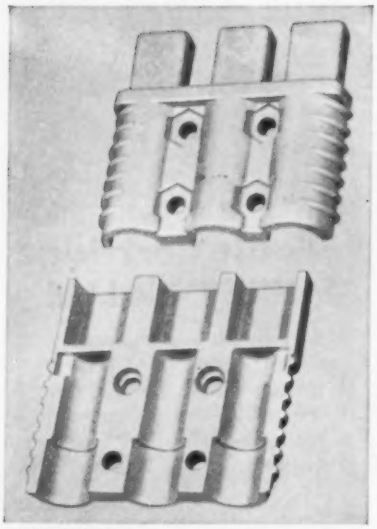
This valve can be furnished with a body and to meet user's pressure and flow requirements.

Write for detailed literature

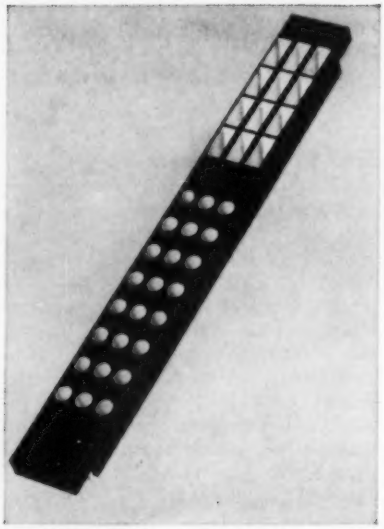
Fluid Regulators CORPORATION

313 Gillette Street • Painesville, Ohio
ELmwood 2-3319

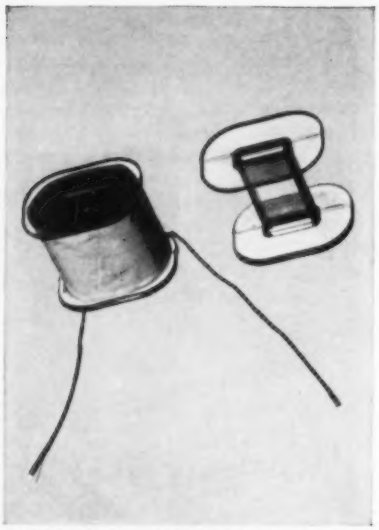
G-E LEXAN® POLYCAR



STRENGTH LEXAN resin has an impact strength of more than 12 foot-pounds per inch of notch — higher than any other plastic! This toughness, plus heat resistance and good electrical properties, make LEXAN resin an outstanding choice for 3-pole connectors used in rugged service on electric trucks.



HEAT STABILITY Lampholder terminal block is used inside electronic equipment where heat is difficult to dissipate. LEXAN polycarbonate resin replaced another thermoplastic which melted under severe thermal conditions. LEXAN has a heat distortion point as high as 290°F. Also keeps high strength in sub-zero cold.



ELECTRICAL PROPERTIES A good dielectric, LEXAN resin is non-corrosive even when used with very fine Class F magnet wire. Coil forms must not distort at temperatures above 200°F under stresses caused by tightly wound wire. LEXAN resin provides high heat distortion temperatures under load.

DESIGN LITERATURE

Russian for Scientists

DENNIS WARD. Macmillan Co, 60 Fifth Ave, NY. 8¼ x 5¼, 204 pp. $3.95.

If you want to read engineering articles in original Russian, without the necessity of first becoming an amateur linguist, this book may provide the answer. It stresses only the essential grammar, passes lightly over pronunciation, and goes on to give do-it-yourself examples based on actual scientific literature. In the beginning chapters, the written (cursive) and printed versions of each word and letter are given, in case you want to write Russian. Included is a 25-page Russian-to-English word list. Author is the Head of the Russian Department of the Univ of Edinburgh.

Elements of Electronics

H V HICKEY & W M VILLINES JR. McGraw-Hill Book Co Inc, 330 W 42nd St, NY 36. 6¼ x 9¼, 549 pp. $6.

A mechanical engineer trying to learn electronics—or a college student preparing for his second year in electronic engineering—can benefit from this simplified but thorough text. Fifty chapters carry the reader from basic physics, through simple devices and circuits, into electrical engineering concepts such as ac machines and theory of inductance, and finally into discussions of tubes, power supplies, transmitters, receivers and transistors. All of the book is in straightforward language; the first edition (of which this is a complete revision) was successful in the training of armed-forces technicians.

Centrifugal Pumps

IGOR KARASSIK & ROY CARTER. F W Dodge Corp, 119 W 40th St, NY 18. 7⅛ x 10, 496 pp. $15.75.

Contains information covering the entire field of centrifugal pumps, their appurtenances, and control. It describes and illustrates most of the common types of pumps, including vertical, self-priming, and regenerative types. Typical chapter headings are: pump performance; controls, drivers, and priming; services and selection; and installation, operation and maintenance. The book primarily is a practical state-of-the-art presentation showing what pumps can do and how they are used, and has many illustrations of pumps and drives. It is not a theoretical-design text. The 15-page data section in the back has many useful hp and pressure-loss charts, equations, and viscosity tables.

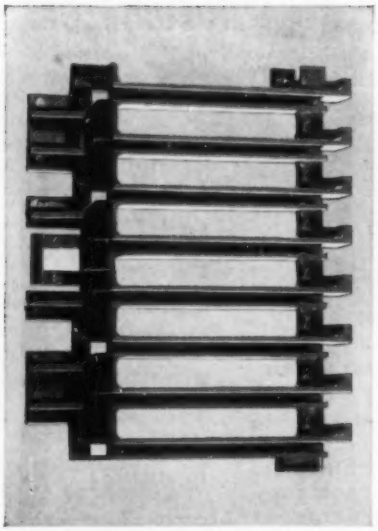
Other Books of Interest

ASTM Standards—Non-Ferrous Metals, Electronic Materials
American Society for Testing Materials, 1916 Race Street, Philadelphia 3. 6 x 9, 348 pp. $4.

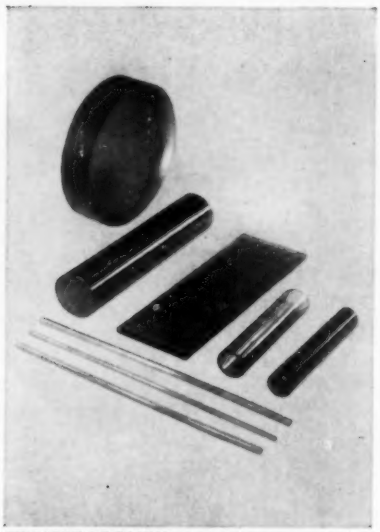
Heat Treatment and Properties of Iron and Steel
T G Digges, S J Rosenberg. National Bureau of Standards, US Dept of Commerce, Washington 25, DC. 8 x 10¼, 40 pp. 35¢.

Relativistic Electron Theory
M E Rose. John Wiley & Sons Inc, 440 Park Ave South, NY 16. 6 x 9½, 302 pp. $9.50.

BONATE RESIN TOUGHEST OF PLASTICS!



DIMENSIONAL STABILITY Card Guide for business machines is molded to close tolerances . . . must undergo minimum change in dimensions during service. Parts show excellent dimensional stability under moist and high temperature conditions. LEXAN resin meets self-extinguishing requirement.



TRANSPARENCY Stock shapes and film of LEXAN polycarbonate resin have excellent transparency. Bar stock is easily machined; film can be thermoformed, heat-sealed and solvent-sealed. Combination of clarity, toughness and malleability gives LEXAN resin the design capabilities of a transparent metal!

LEXAN OPENS UP NEW OPPORTUNITIES... Even before LEXAN entered large-scale production, manufacturers, impressed by its exceptional properties, developed and field tested over 300 applications. G.E. participated in these developments. With the opening of new G-E facilities capable of producing millions of pounds of LEXAN per year, the price of this versatile thermoplastic has dropped dramatically – over 40% in a single year. This fact alone has brought many new products within the range of feasibility. Can you afford to overlook the opportunities presented by LEXAN? Send for details on price, properties, applications and G-E's technical assistance program today! General Electric, Chemical Materials Department, Section PE-41, Pittsfield, Mass.

LEXAN®
Polycarbonate Resin

GENERAL ELECTRIC

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Mechanics of Solids and Fluids
R R Long. Prentice-Hall Inc, Englwood Cliffs, NJ. 6 x 9¼, 156 pp. $9.

Transcendental & Algebraic Numbers
A O Gelfond. Dover Publications Inc, 180 Varick St, NY 14. 5¼ x 8, 190 pp. $1.75.
An English translation of the first Russian edition.

Algebraic Equations
E Dehn. Dover Publications Inc, 180 Varick St, NY 14. 5¼ x 8, 208 pp. $1.45.
Unabridged and corrected paperback edition of work first published in 1930.

ABSTRACTS FROM THE LITERATURE

Reliability in Relays

With the "envelope" established by the technical requirements of existing specifications, standard relays can be and are being produced significantly more reliable than the minimum called for by the specifications. In fact, all standard relays can be made even more reliable by certain variations in material, design or construction detail, which are already known to relay manufacturers, and can be incorporated into the product provided there is an incentive to do so.

The procedure described in this paper proposes that specified test procedures should be revised to provide: (1) a method of classifying relays into different levels of reliability by specifying appropriate life test sampling procedures, and (2) an incentive to improve relay reliability by means of a qualification provision which identifies each relay with the reliability level it has attained.

"Reliability Provisions in Specifications for Relays," by Charles J. Brzezinski, Office of the Assistant Secretary of Defense (Supply & Logistics). Published in NARM Relay Symposium Papers at 8th Annual Relay Symposium at Stillwater, Okla.

Valve Sizing for Flashing Liquids

Of the various methods proposed for sizing control valves for flashing liquids, the one based on the downstream density of the liquid-vapor mixture seems the most accurate. With the aid of specially constructed curves and known inlet conditions, the instrument engineer can size a valve with a few simple calculations. The author explains the development and use of such curves, and presents usable charts covering six of the more common process fluids.

"Accurate Valve Sizing for Flashing Liquids," by A J Hanssen, Conoflow Corp. Control Engineering, Feb '61, p. 87, 330 W 42 St, New York 36.

Adjustable-speed Drives

Discusses speed, control and braking characteristics and capabilities of some types of variable speed drives, such as motor-generators, electronic rectifier, saturable reactor, metallic rectifier, eddy-current coupling, mechanical.

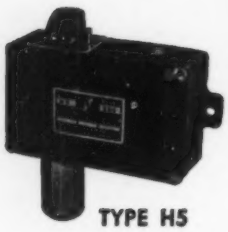
"How to Select an Adjustable-speed Drive," J. W. Harper, General Electric Co. American Machinist/Metalworking Manufacturing, Dec 12, '60, 330 W 42nd St, New York 36.

Cushioning Materials

The increased use of energy-absorbing materials in modern technology has necessitated laboratory study of these materials and compilation of data for use in system design. The paper consists of three parts. The first discusses the scaling law for a general

continued on page 95

External Adjustment & Calibration on PRESSURE & VACUUM CONTROLS H5 H12



TYPE H5

TYPE H12

UNITED ELECTRIC designed these controls for industrial applications where outside adjustment and calibration are important factors. Types H5 and H12 accurately and sensitively control liquid level alarms and air gas pressures. The type H5 (minimum 2 psi differential) controls up to a maximum of 500 psi, and the type H12 (minimum 3″ wc differential) up to 180 psi. Uncalibrated, internally adjusted versions of these controls are available as type J7 and type J6 respectively.

Switch Differential	H5 — Uniform on-off differential, fixed from 2 psi to 30 psi. H12 — Uniform on-off differential, fixed from 3″ wc to 2 psi.
Switch Ratings	15 amps. at 115 or 230 volts AC, also 20 amps. or DC switches on specification.
Switch Types	N.O., N.C., or Double Throw, no neutral position.
Size & Weight	H5 — 5⅛″ x 4⅞″ x 1½″ . . . weighs approx. 1 lb. H12 — ¾″ x 2¾″ x 5″ weighs approx. 1 lb. 6 oz.
Electrical Connection	Conduit opening in enclosure — ⅞″ O.D. Internally-located terminal block.
Enclosure	Die-cast aluminum case with black wrinkle finish.
Mounting	H5 — Directly, by ¼″ female NPT on bellows housing; or surface mounted by mounting ears on each end of case. H12 — Directly, by ¼″ female NPT on bellows housing.
Bellows	H5 — Spring loaded, seamless brass, stainless steel or monel. H12 — Spring loaded, seamless brass bellows.
Pressure Connections	¼″ female NPT.

UNITED ELECTRIC *manufactures a complete line of temperature, pressure, and vacuum controls. UE will gladly modify or custom-build a unit to meet your specifications. Consult a UE application engineer today.*

Write for Bulletin No. 5-5 for complete H5 data and Bulletin No. 5-2 for complete H12 data.

UE® United Electric Controls COMPANY
80 SCHOOL STREET, WATERTOWN, MASS.

molded in one-piece.. 2 durometers

Drain Manifold 60 and 80 Durometer

Dual durometer process lets you combine hard-soft sections in one piece . . . with one-operation economy. Ask to see samples!

eliminates fabricating costs!

■ *improves quality!*

■ *increases design flexibility!*

GEAUGA INDUSTRIES CO.
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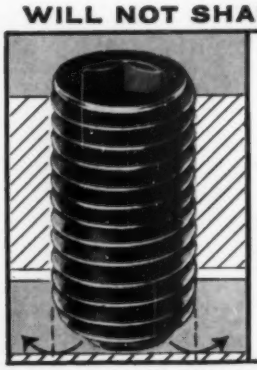
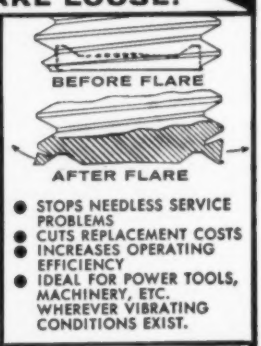
MIDDLEFIELD, OHIO

CIRCLE 214 ON READER SERVICE CARD

new setko FLARE-LOK SET SCREW WILL NOT SHAKE LOOSE!





- STOPS NEEDLESS SERVICE PROBLEMS
- CUTS REPLACEMENT COSTS
- INCREASES OPERATING EFFICIENCY
- IDEAL FOR POWER TOOLS, MACHINERY, ETC. WHEREVER VIBRATING CONDITIONS EXIST.

HERE'S HOW IT WORKS: The point of the FLARE-LOK set screw is specially formed to flare out when it is tightened against a bearing surface. The thread gap is closed just enough to prevent loosening or shaking free due to vibration, etc. Yet, the screw may be removed without damaging the mating threads. You can get them in hex socket, slabbed or slotted heads.

WRITE FOR FREE "FLARE-LOK" TEST SAMPLES and full information TODAY.

SETKO Set Screw & Mfg. Co.
153 Main Street, Bartlett, Illinois

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cushioned system. The second part introduces a simpler scaling law which applies when the system satisfies certain conditions relating to the geometry of the system and the nature of the material. The third section presents data on a variety of materials in the higher energy ranges. Included are some foamed plastics rubber compounds, metal honeycombs, and foamed metals.

"Data Presentation for Cushioning Materials," by W. G. Soper, R. C. Dover, University of Mexico. Presented at the 17th Annual Technical Conference, SPE, 65 Prospect St, Stamford, Conn.

CATALOGS AND BULLETINS

To obtain copies of literature described below, circle corresponding number on postcard inside back cover.

VARIABLE-SPEED DRIVES—Catalog G-100, 88 pp. Tables cover output speeds; torque and hp capacities and prices of models in the ¼ to 40-hp range. Dimension diagrams and data for over 100 assemblies are included. Large cutaways show design features. Reliance Electric & Engineering Co, 23701 Euclid Ave, Cleveland 17.

Circle 350 on Reader Service Card

MINIATURE BEARINGS—Catalog 3E, 16 pp. Contains dimensional data, including load factors, and outline of tolerances to which radial flanged, radial without inner race, pivot, miniature roller and other types of bearings are made. Includes dimensional drawings and cross-section sketches showing how bearings are installed. Landis & Gyr Inc, 45 W 45th St, New York 36.

Circle 351 on Reader Service Card

METAL FASTENERS AND CORROSION RESISTANCE—Brochure Vol 24, No 1, 24 pp. Analyzes seven basic types of corrosion and shows what kinds of metals best resist them. Chart lists 136 corrosive agents and eight metal types that resist each of them. Chemically equivalent specifications of metal fasteners are cross-indexed, while chemical and mechanical properties are spelled out for each metal and alloy used in fasteners. H M Harper Co, Morton Grove, Ill.

Circle 352 on Reader Service Card

ALUMINUM HARD COATINGS—Engineering report, 7 pp. Discusses hard-anodized coatings for upping aluminum-alloy wear-resistance and gives specific cost figures. Details physical properties and results of hardness studies, as well as illustrating effect of coating on part dimen-

continued on page 96

NEEDED:
VIBRATION ISOLATION
AT BOTH HIGH AND
LOW FREQUENCIES

A mount soft enough to isolate vibration in the upper range of frequencies generally gives trouble with a low natural frequency. With sensitive precision equipment, such as airborne sighting mechanisms, for example, a mount must work at *both* ends of the frequency spectrum.

ANSWER:
MB ISO-DAMP(tm) MOUNTS
CONTROL FULL
FREQUENCY RANGE

Resilient rubber sections with equal spring rates in all directions (an original MB mount principle) give the MB Isomode Mount its high frequency isolation efficiency in any position. In the low range, a unique damping mechanism effectively restricts resonant build-up; does not affect high frequency isolation. Unit also meets MIL-E-5272-A shock requirements.

WHAT'S YOUR
MOUNT PROBLEM?

Iso-Damp mounts can be modified to meet your particular requirements. Or possibly one of MB's other standard mounts may be the answer to your special vibration control problem. Why not let MB's experienced specialists help find the right answer for you. Write us for complete information—ask for Bulletin 418-4.

MB ELECTRONICS
A DIVISION OF TEXTRON ELECTRONICS, INC.
1076 State Street, New Haven 11, Conn.

sions. Curves compare hard coating's abrasion resistance and number of wear cycles with that of other materials and coatings. Allen Aircraft Products Inc, PO Box 271, Ravenna, Ohio.

Circle 353 on Reader Service Card

TRANSFORMERS—Catalog CS-101, 36 pp. Supplies dimensions and electrical specifications of approx 900 stock units, ranging from military standard to low-cost commercial grades. Where applicable, performance curves are given. Chicago Standard Transformer Corp, 3501 W Addison St, Chicago 18.

Circle 354 on Reader Service Card

VARIABLE-SPEED BELTS—Brochure, 8 pp. Lists outside circumference, top width and number of links in belting equivalent in sizes to three other manufacturers' rubber and wood block belts. Includes data on how to measure, install and compute prices of types with top widths ranging from $1\frac{1}{32}$ to 5 in. Manheim Mfg & Belting Co, Manheim, Penna.

Circle 355 on Reader Service Card

COATED FABRICS—Catalog SF-12/60-15M, 12 pp. Outlines physical properties, performance characteristics and applications of more than 200 fabrics, including cotton, nylon, Orlon, Dacron, silk, fiberglass and blends, coated with Buna-N, Neoprene, natural rubber and special-purpose elastomers. Tables list characteristics of eight textile fibers, effects of chemicals on 12 elastomers and a comparison of elastomer properties. Vulcan Div, Reeves Bros Inc, 1071 Ave of the Americas, New York 18.

Circle 356 on Reader Service Card

POLYESTER RESINS—Booklets, 12 and 8 pp. Former describes characteristics, fabricating procedures and end uses of 24 formulations. Latter covers spray-up techniques; safety procedures; coloring and measuring. Includes chart indicating catalyst concentration to be used with varying quantities of resin. Plastics & Resins Div, American Cyanamid Co, Wallingford, Conn.

Circle 357 on Reader Service Card

VALVES AND FITTINGS—Catalog 60, 464 pp. Describes and illustrates hundreds of valves and fittings for domestic, industrial, chemical, hydraulic and other applications and traces their dimensions, weights and capacities. Discusses metals and materials used along with their chemical and strength characteristics. Crane Co, 4100 S Kedzie Ave, Chicago 32.

Circle 358 on Reader Service Card

WELDED STEEL FOR THIN FLAT STRUCTURES—Study report, 4 pp. Discusses and illustrates use of welded steel in designing machine-tool tables, loading ramps and similar structures to improve rigidity and save weight. Contains formulas for estimating deflection of frame under torsional load and for calculating torsional resistance of some standard structural shapes. Lincoln Electric Co, Cleveland 17.

Circle 359 on Reader Service Card

LAMINATED PLASTICS, VULCANIZED FIBER—Condensed catalog, 8 pp. Carries physical, mechanical and electrical properties; suggested applications, corresponding NEMA grades; military specs; and colors; forms and sizes of 21 laminated plastic grades and six vulcanized fibers. Taylor Fibre Co, Norristown, Penna.

Circle 360 on Reader Service Card

DRILLING AND TAPPING FOR INSERTS—Bulletin 765, 12 pp. Explains proper procedures for drilling and tapping aluminum, magnesium, steel, thermoplastics and other plastics to receive inserts, and discusses tapping problems, their causes and suggested remedies. Also treats proper selection of tap for boss material, tapping lubricants, close-in characteristics of magnesium and class of fit. Nomograph determines tapping speed and lubricant

WHY AIR FORCE HAS ADOPTED MICROFILM FOR ENGINEERING DRAWINGS

Recently the Air Force issued new contract requirements of vital importance to companies that are doing—or intend to do—business with its various activities. In essence, the Air Force has made the use of microfilm mandatory for most engineering data and records relating to items delivered by contractors and their vendors.

The new requirements (MCP-71-77) incorporate standards and specifications issued earlier by the Department of Defense for its Engineering Data Micro-Reproduction System. The Air Force move is indicative of the importance of microfilm to the government in saving time, money, and space.

The Air Force is convinced that working with microfilm is easier than working with paper, that it is more efficient and costs less. Filmwork, in other words, is easier and more practical than paperwork for engineering drawings and records.

This is not news to the many industries that use microfilm today. They know that microfilm is a highly efficient and effective production communication tool. They know that microfilm can do many jobs much faster and much more accurately, with almost fantastic savings in time and money.

3M makes microfilm easy to use

for given size of tapped thread in wide material range. Heli-Coil Corp, Danbury, Conn.

Circle 361 on Reader Service Card

MINIATURE PANEL METERS–Catalog, 4 pp. Illustrates, describes performance and gives specifications of 1-in. barrel-dia models; 1½-in. ruggedized and long-scale types; and side-indicator units. International Instruments Inc, 88 Marsh Hill Rd, Orange, Conn.

Circle 362 on Reader Service Card

HIGH-SPEED ROTARY SWITCHES–Brochure, 6 pp. Contains considerations in designing own switch for telemetering, programming, commutating, sampling, etc. Data includes description and outline drawings of two standard switch styles; pole types and styles; speeds; motors; and environmental capabilities. Instrument Development Laboratories Inc, Attleboro, Mass.

Circle 363 on Reader Service Card

CHAIN PITCH SIZES–Wall chart, 9 x 12 in. Lists design hp on vertical axis and rpm speeds for small sprocket on horizontal axis. Intersection of two lines gives recommended pitch size for power transmission chain. Foote Bros Gear & Machine Corp, Dept MJ, 4545 S Western Blvd, Chicago 9.

Circle 364 on Reader Service Card

DETACHABLE HOSE FITTINGS–Catalog, 8 pp. Specification tables, illustrated with cutaways, cover reusable fittings and assemblies for medium- and high-pressure uses. Sketches show step-by-step assembly. Lenz Co, 3301 Klepinger Rd, Dayton 1, Ohio.

Circle 365 on Reader Service Card

AUTOMOTIVE, INDUSTRIAL HARDWARE–Catalog 38-133, 14 pp. Carries photographs, specifications, and dimensional drawings and data of hood catches; barrel-type fasteners; hooking brackets; utility and heavy-duty grab handles; door holders; and dovetails and wedges. Stewart-Warner Corp, 1826 W Diversey Pkwy, Chicago 14.

Circle 366 on Reader Service Card

PART-WINDING STARTING MOTORS–Bulletin 1465, 2 pp. Discusses features of three types and plots torque characteristics and connections for part-winding starting. Century Electric Co, 18th & Pine Sts, St Louis 3.

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EPOXY TUBING–Bulletin, 2 pp. Describes and gives specifications and sizes of polyester and epoxy-reinforced glass rods, tubes and shapes. Polygon Plastic Co, Walkerton, Ind.

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COUNTING INSTRUMENTS–Catalog 608.462, 6 pp. Illustrates and outlines specifications of dustproof and hermetically sealed coin counters, automatic batch counters, actuating switches and photoelectric equipment. Automation Controls Div, General Controls Co, 8080 McCormick Blvd, Skokie, Ill.

Circle 369 on Reader Service Card

PICKUPS AND AMPLIFIERS–Bulletin 115, 2 pp. Tabulates physical and electrical specifications of magnetic generating coils used in turbine flow sensors to convert rotor motion into an ac signal and in tachometers or other motion-sensing applications. Waugh Engineering Co, 7842 Burnet Ave, Van Nuys, Calif.

Circle 370 on Reader Service Card

BALL VALVES–Brochure, 4 pp. Discusses and illustrates design features of valves for hydrocarbon service at process temperatures below 400 F. Also contains dimensional data and drawings. Jamesbury Corp, Worcester, Mass.

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TURBINE FLOWMETERS – Bulletin 10C1505, 6 pp. Outlines performance characteristics, process and electrical connections for two propeller-type flowmeters that transduce liquid velocity to

continued on page 99

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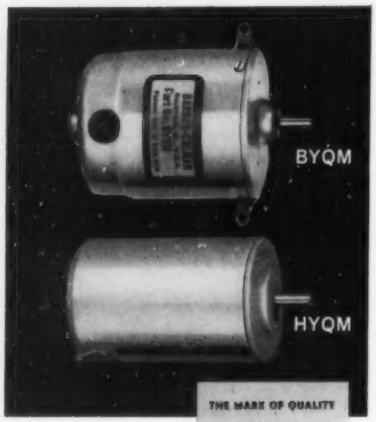

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METAL-FINISHING NOZZLES–Bulletin 106, 6 pp. Recommends types of nozzles to use in washing, rinsing, fogging or wetting, coating and related operations. Outlines materials, capacities, spray angles and dimensions of flat spray and hollow and full cone spray types. Spraying Systems Co, 3201 Randolph St, Bellwood, Ill.

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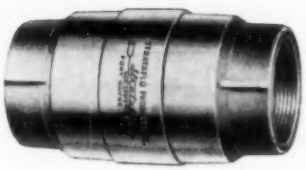

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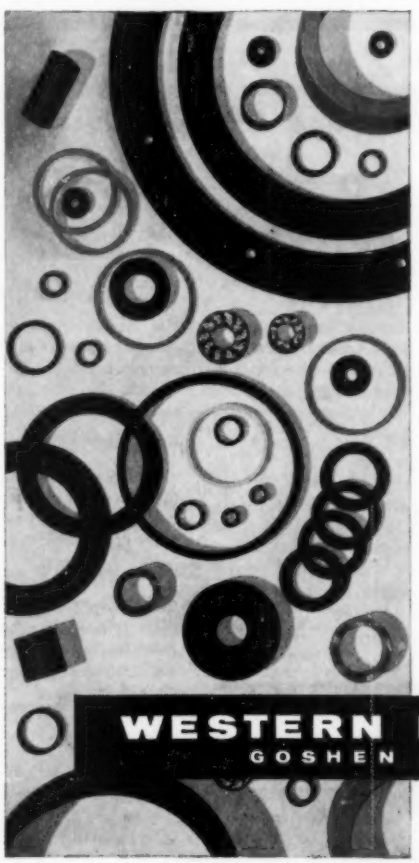

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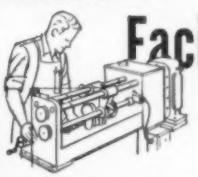

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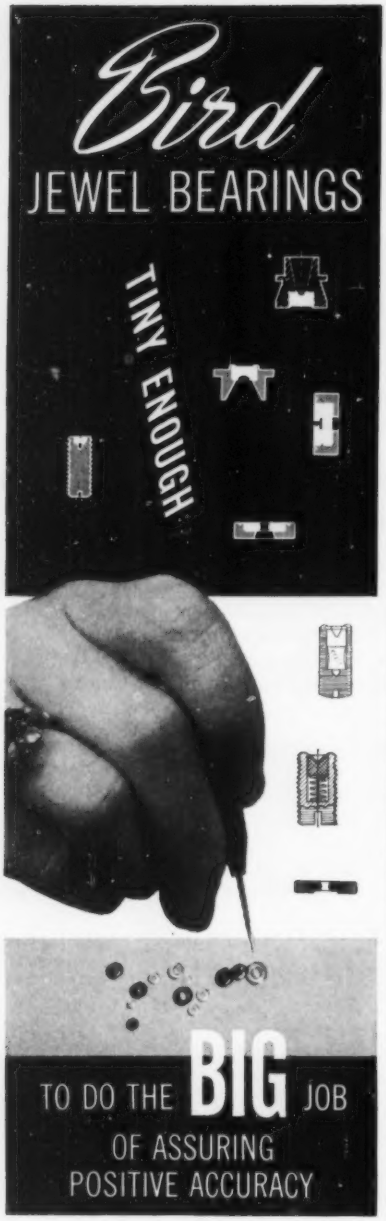

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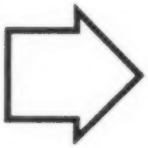

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353—Aluminum Hard Coatings, 7 pp, Allen Aircraft Products Inc.
359—Welded Steel for Thin Flat Structures, 4 pp, Lincoln Electric Co.
375—Clad Metals, 2 pp, Accurate Specialties Co.
376—Brazing Alloy, data sheet, Wall Colmonoy Corp.

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357—Polyester Resins, 12 & 8 pp, Ameri-Can Cyanamid Co.
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368—Epoxy Tubing, 2 pp, Polygon Plastic Co.

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355—Variable Speed Belts, 8 pp, Manheim Mfg & Belting Co.
364—Chain Pitch Sizes, chart 9 x 12 in., Foote Bros Gear & Machine Corp.

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351—Miniature Bearings, 16 pp, Landis & Gyr Inc.
366—Automotive, Industrial Hardware, 14 pp Stewart-Warner Corp.
368—Epoxy Tubing, 2 pp, Polygon Plastic Co.
374—Metal Finishing Nozzles, 6 pp, Spraying Systems Co.

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361—Drilling and Tapping for Inserts, 12 pp, Heli-Coil Corp.

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373—Servomotors, 4 pp, National Pneumatic Co Inc.

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369—Counting Instruments, 6 pp, General Controls Co.
370—Pickups and Amplifiers, 2 pp, Waugh Engineering Co.
372—Turbine Flowmeters, 6 pp, Fischer & Porter Co.

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365—Detachable Hose Fittings, 8 pp, Lenz Co.
371—Ball Valves, 4 pp, Jamesbury Corp.
372—Turbine Flowmeters, 6 pp, Fischer & Porter Co.

331—Nylon Cable Clamp
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What synthetic sealing materials should I use—and when

Environmental conditions generally dictate the type of synthetic rubber for a specific oil sealing application.

Where temperature, shaft speed, runout, eccentricity, and lubricant type are "normal", standard Buna N synthetic rubber compounds are satisfactory. If, however, the application is "dry running", a compound must be selected that will operate satisfactorily with a very small amount of lubricant. If the application involves excessive abrasion, highly "loaded" compound stocks should be provided. At temperatures over 250° F polyacrylics or silicone compounds are indicated; if high temperature is accompanied by a solvent base or additive lubricant, polyacrylics are definitely preferred.

Thus many variables govern successful oil sealing. The chart below gives more data; for complete information from the world's foremost oil seal laboratories, call your National Seal engineer. He's in the Yellow Pages, under Oil Seals or O-Rings.

SYNTHETIC RUBBER COMPOUNDS | **RECOMMENDED APPLICATIONS**

Comp. No.	Base Polymer	Min/Max Operating Temperature	Life Index	Price Index	Automatic Transmissions	Pinions	Axle Seals	Engine Seals	Misc. Applications
B-63	Buna N	—40°F/225°F	100	100				Excellent for small gas engines.	Excellent for small non-spring loaded seals.
B-86	Buna N	—30°F/225°F	100	100		Satisfactory for medium temperature applications.	Truck and automotive rear axles. General use.	Satisfactory as general purpose material where temperature permits.	General purpose Buna N applications.
B-94	Buna N	—60°F/250°F	100	100					Excellent against aromatics and some military aircraft oils, fuels.
B-95	Buna N	—30°F/225°F	100	100					Good dry running compounds for applications requiring high durometer stock.
C-6	Buna N	—30°F/225°F	100	100			Excellent for semi-rough axles. Has good wear qualities.		Good for pressure seals due to high durometer and clean trimming.
L-28	Acrylon BA-12	—30°F/300°F	400	125	Good for temperature range indicated.	Satisfactory in single lip construction.	Sealed bearing high temperature applications.	Satisfactory for automotive use. High temperatures.	Satisfactory for high temperature general applications. Can be used with EP or GL-4 oils.
L-34	Hycar PA-21	0°F/300°F	400	115	Good for temperature range indicated.	Dual lip limited contact for high temperatures.	Sealed bearing high temperature applications.	Satisfactory for automotive use. High temperatures.	Satisfactory for high temperature general single or dual lips. Ok with EP or GL-4 oils.
S-48	Silicone*	—80°F/400°F	1500	150	Excellent high and low temperature life.	Silicone Compounds Not Recommended With EP Lubricants at high temperatures.		Excellent for general engine use. Suggested for premium gasoline and Diesel engines.	Excellent wide range material. Avoid use in EP and GL-4 oils.
S-49	Silicone*	—80°F/300°F	600	130	Good at high and low temperatures.			Very good for general engine use; premium gasoline and Diesel engines.	Very good wide range material. Avoid use in EP and GL-4 oils.

*Silicones require special stabilization for satisfactory use in aromatic oils at high temperatures.

NATIONAL SEAL
Division, Federal-Mogul-Bower Bearings, Inc.
GENERAL OFFICES: Redwood City, California
PLANTS: Van Wert, Ohio; Redwood City and Downey, California

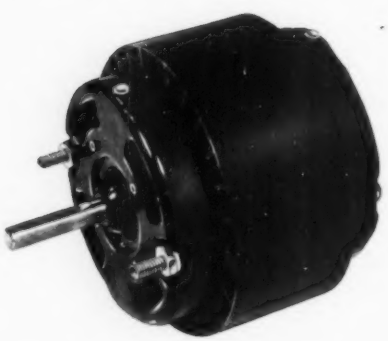
CIRCLE 202 ON READER SERVICE CARD

CONSTANT SPEED AND TORQUE OF **EMERSON ELECTRIC MOTORS**

is assured by balanced Die-Cast Rotors

The precision tolerances of the rotors in Emerson Electric Motors insure a uniform air gap for constant speed and torque. Noise and vibration are kept to a minimum by the symmetrical rotor design that provides a porous-free casting. The rotor is supported on each side to decrease the bearing load and give your application long, trouble-free operation.

EMERSON ELECTRIC MOTORS are custom engineered to suit your specific needs. Call us *today*—you'll like our way of doing business!



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